[d] When a conductor joins the lower nodes of the two separate parts, there is now only a single part in the circuit. There would now be 4 nodes, because the two lower nodes are now joined as a single node. The number of branches remains at 7, where each branch contains one of the seven individual circuit components.

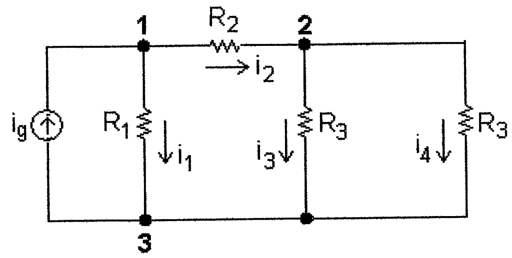
P 4.4 [a] From Problem 4.2(d) there are 10 essential branches were the current is unknown, so we need 10 simultaneous equations to describe the circuit.

[b] From Problem 4.2(f), there are 5 essential nodes, so we can apply KCL at $(5-1) = 4$ of these essential nodes. There would also be two dependent source constraint equations.

[c] The remaining 4 equations needed to describe the circuit will be derived from KVL equations.

[d] We must avoid using the meshes containing current sources, as we have no way of determining the voltage drop across a current source.

P 4.5



[a] At node 1: $\quad -i_g + i_1 + i_2 = 0$

At node 2: $\quad -i_2 + i_3 + i_4 = 0$

At node 3: $\quad i_g - i_1 - i_3 - i_4 = 0$

[b] There are many possible solutions. For example, solve the equation at node 1 for i_g:

$i_g = i_1 + i_2$

Substitute this expression for i_g into the equation at node 3:

$(i_1 + i_2) - i_1 - i_3 - i_4 = 0 \qquad \text{so} \qquad i_2 - i_3 - i_4 = 0$

Multiply this last equation by -1 to get the equation at node 2:

$-(i_2 - i_3 - i_4) = -0 \qquad \text{so} \qquad -i_2 + i_3 + i_4 = 0$

P 4.6 Use the lower terminal of the 5 Ω resistor as the reference node.

$$\frac{v_o - 60}{10} + \frac{v_o}{5} + 3 = 0$$

Solving, $\quad v_o = 10$ V

P 4.7 [a] From the solution to Problem 4.5 we know $v_o = 10$ V, therefore

$$p_{3\text{A}} = 3v_o = 30 \text{ W}$$

$$\therefore \quad p_{3\text{A}} \text{ (developed) } = -30 \text{ W}$$

[b] The current into the negative terminal of the 60 V source is

$$i_g = \frac{60 - 10}{10} = 5 \text{ A}$$

$$p_{60\text{V}} = -60(5) = -300 \text{ W}$$

$$\therefore \quad p_{60\text{V}} \text{ (developed) } = 300 \text{ W}$$

[c] $p_{10\Omega} = (5)^2(10) = 250$ W

$$p_{5\Omega} = (10)^2/5 = 20 \text{ W}$$

$$\sum p_{\text{dev}} = 300 \text{ W}$$

$$\sum p_{\text{dis}} = 250 + 20 + 30 = 300 \text{ W}$$

P 4.8 [a] $\dfrac{v_0 - 60}{10} + \dfrac{v_o}{5} + 3 = 0; \qquad v_o = 10$ V

[b] Let v_x = voltage drop across 3 A source

$$v_x = v_o - (10)(3) = -20 \text{ V}$$

$$p_{3\text{A}} \text{ (developed) } = (3)(20) = 60 \text{ W}$$

[c] Let i_g = be the current into the positive terminal of the 60 V source

$$i_g = (10 - 60)/10 = -5 \text{ A}$$

$$p_{60\text{V}} \text{ (developed) } = (5)(60) = 300 \text{ W}$$

[d] $\sum p_{\text{dis}} = (5)^2(10) + (3)^2(10) + (10)^2/5 = 360$ W

$$\sum p_{\text{dis}} = 300 + 60 = 360 \text{ W}$$

[e] v_o is independent of any finite resistance connected in series with the 3 A current source

P 4.9 $2.4 + \dfrac{v_1}{125} + \dfrac{v_1 - v_2}{25} = 0$

$$\frac{v_2 - v_1}{25} + \frac{v_2}{250} + \frac{v_2}{375} - 3.2 = 0$$

Solving, $v_1 = 25$ V; $\qquad v_2 = 90$ V

CHECK:

$$p_{125\Omega} = \frac{(25)^2}{125} = 5 \text{ W}$$

$$p_{25\Omega} = \frac{(90-25)^2}{25} = 169 \text{ W}$$

$$p_{250\Omega} = \frac{(90)^2}{250} = 32.4 \text{ W}$$

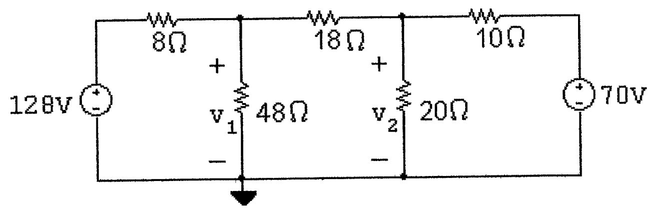
$$p_{375\Omega} = \frac{(90)^2}{375} = 21.6 \text{ W}$$

$$p_{2.4\text{A}} = (25)(2.4) = 60 \text{ W}$$

$$\sum p_{\text{abs}} = 5 + 169 + 32.4 + 21.6 + 60 = 288 \text{ W}$$

$$\sum p_{\text{dev}} = (90)(3.2) = 288 \text{ W} \quad \text{(CHECKS)}$$

P 4.10 [a]



$$\frac{v_1 - 128}{8} + \frac{v_1}{48} + \frac{v_1 - v_2}{18} = 0$$

$$\frac{v_2 - v_1}{18} + \frac{v_2}{20} + \frac{v_2 - 70}{10} = 0$$

In standard form,

$$v_1\left(\frac{1}{8} + \frac{1}{48} + \frac{1}{18}\right) + v_2\left(-\frac{1}{18}\right) = \frac{128}{8}$$

$$v_1\left(-\frac{1}{18}\right) + v_2\left(\frac{1}{18} + \frac{1}{20} + \frac{1}{10}\right) = \frac{70}{10}$$

Solving, $v_1 = 96$ V; $v_2 = 60$ V

$$i_a = \frac{128-96}{8} = 4 \text{ A}$$

$$i_b = \frac{96}{48} = 2 \text{ A}$$

$$i_c = \frac{96-60}{18} = 2 \text{ A}$$

Therefore, the dependent source is developing 1484 W.
CHECK:

$p_{125\text{V}} = 125i_2 = 150$ W (left source)

$p_{125\text{V}} = -125i_3 = -250$ W (right source)

$\sum p_{\text{dev}} = 1484 + 250 = 1734$ W

$p_{35\Omega} = (1.2)^2(35) = 50.4$ W

$p_{85\Omega} = (2)^2(85) = 340$ W

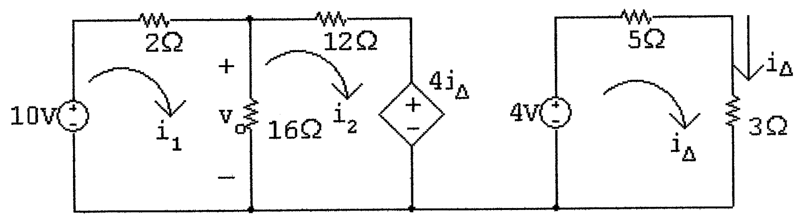
$p_{15\Omega} = (7 - 1.2)^2(15) = 504.6$ W

$p_{25\Omega} = (7 - 2)^2(25) = 625$ W

$p_{100\Omega} = (1.2 - 2)^2(100) = 64$ W

$\sum p_{\text{diss}} = 50.4 + 340 + 504.6 + 625 + 64 + 150 = 1734$ W

P 4.40 [a]



$10 = 18i_1 - 16i_2$

$0 = -16i_1 + 28i_2 + 4i_\Delta$

$4 = 8i_\Delta$

Solving, $i_1 = 1$ A; $\quad i_2 = 0.5$ A; $\quad i_\Delta = 0.5$ A

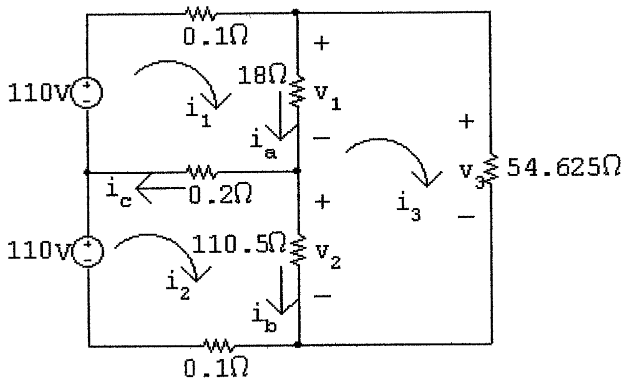
$v_0 = 16(i_1 - i_2) = 16(0.5) = 8$ V

[b] $p_{4i_\Delta} = 4i_\Delta i_2 = (4)(0.5)(0.5) = 1$ W (abs)

$\therefore\ p_{4i_\Delta}$ (deliver) $= -1$ W

P 4.52 [a] Both the mesh-current method and the node-voltage method require three equations. The mesh-current method is a bit more intuitive due to the presence of the voltage sources. We choose the mesh-current method, although technically it is a toss-up.

[b]



$$110 = 18.3i_1 - 0.2i_2 - 18i_3$$

$$110 = -0.2i_1 + 110.8i_2 - 110.5i_3$$

$$0 = -18i_1 - 110.5i_2 + 183.125i_3$$

Solving, $i_1 = 10$ A; $i_2 = 5$ A; $i_3 = 4$ A

$$v_1 = 18(i_1 - i_3) = 108 \text{ V}$$

$$v_2 = 110.5(i_2 - i_3) = 110.5 \text{ V}$$

$$v_3 = 54.625i_3 = 218.5 \text{ V}$$

[c] $p_{R1} = (i_1 - i_3)^2(18) = 648$ W

$p_{R2} = (i_2 - i_3)^2(110.5) = 110.5$ W

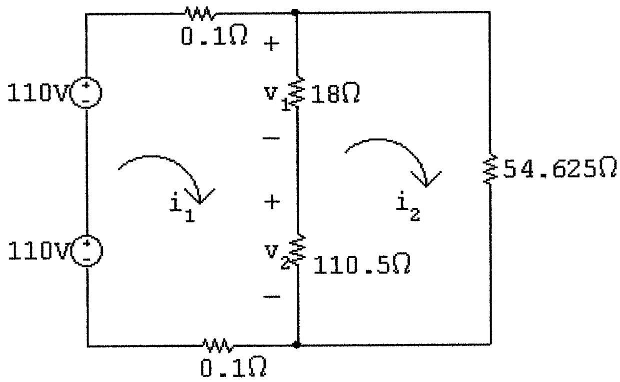
$p_{R3} = i_3^2(54.625) = 874$ W

[d] $\sum p_{\text{dev}} = 110(i_1 + i_2) = 1650$ W

$\sum p_{\text{load}} = 1632.5$ W

$$\% \text{ delivered} = \frac{1632.5}{1650} \times 100 = 98.94\%$$

[e]



$220 = 128.7i_1 - 128.5i_2$

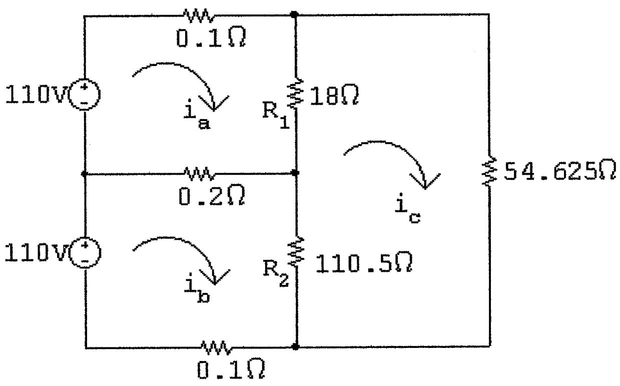
$0 = -128.5i_1 + 183.125i_2$

Solving, $i_1 = 5.71$ A; $\quad i_2 = 4.01$ A

$$\begin{aligned} i_1 - i_2 &= 1.7 \text{ A} \\ v_1 &= (1.7)(18) = 30.6 \text{ V} \\ v_2 &= (1.7)(110.5) = 187.85 \text{ V} \end{aligned}$$

Note v_1 is low and v_2 is high. Therefore, loads designed for 110 V would not function properly, and could be damaged.

P 4.53



$110 = (R + 0.3)i_a - 0.2i_b - Ri_c$

$110 = -0.2i_a + (R + 0.3)i_b - Ri_c$

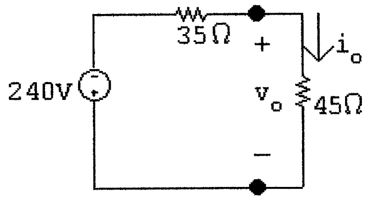
$\therefore \quad (R + 0.3)i_a - 0.2i_b - Ri_c = -0.2i_a + (R + 0.3)i_b - Ri_c$

$\therefore \quad (R + 0.3)i_a - 0.2i_b = -0.2i_a + (R + 0.3)i_b$

$\therefore \quad (R + 0.5)i_a = (R + 0.5)i_b$

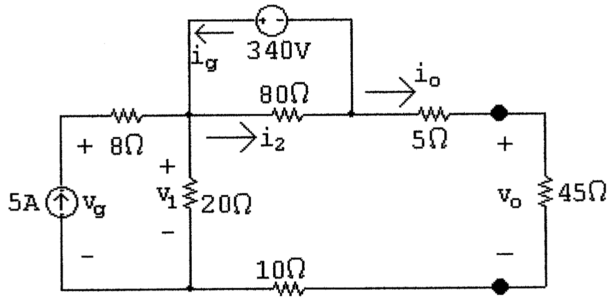
Thus, $\quad i_a = i_b \quad$ so $\quad i_o = i_b - i_a = 0$

which simplifies to



$$\therefore \quad v_o = \frac{45}{80}(-240) = -135 \text{ V}; \qquad i_o = \frac{-135}{45} = -3 \text{ A}$$

[b] Return to the original circuit with $v_o = -135$ V and $i_o = -3$ A:



$$i_g = \frac{340}{80} - (-3) = 7.25 \text{ A}$$

$$p_{340\text{V}} = -(340)(7.25) = -2465 \text{ W}$$

Therefore, the 340 V source is developing 2465 W.

[c] $v_1 = 340 + 60i_o = 340 - 180 = 160$ V

$$v_g = v_1 + 5(8) = 160 + 40 = 200 \text{ V}$$

$$p_{5\text{A}} = -(5)(200) = -1000 \text{ W}$$

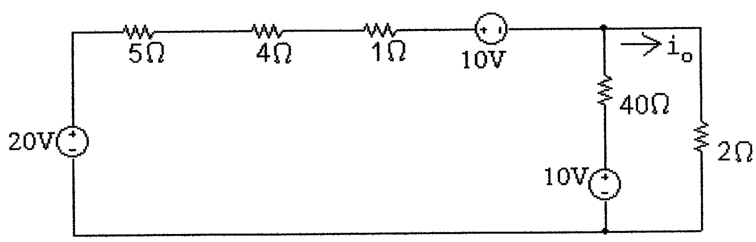
Therefore the 5 A source is developing 1000 W.

[d] $\sum p_{\text{dev}} = 2465 + 1000 = 3465$ W

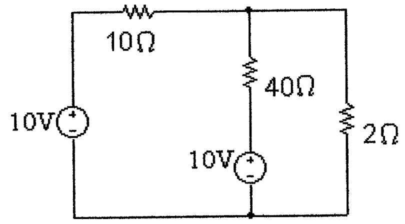
$$\sum p_{\text{diss}} = (5)^2(8) + (8)^2(20) + (4.25)^2(80) + (3)^2(60) = 3465 \text{ W}$$

$$\therefore \quad \sum p_{\text{diss}} = \sum p_{\text{dev}}$$

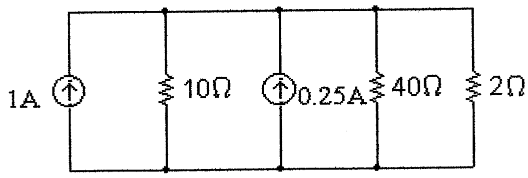
P 4.62 [a] Applying a source transformation to each current source yields



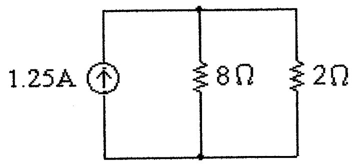
Now combine the 20 V and 10 V sources into a single voltage source and the 5 Ω, 4 Ω and 1 Ω resistors into a single resistor to get



Now use a source transformation on each voltage source, thus

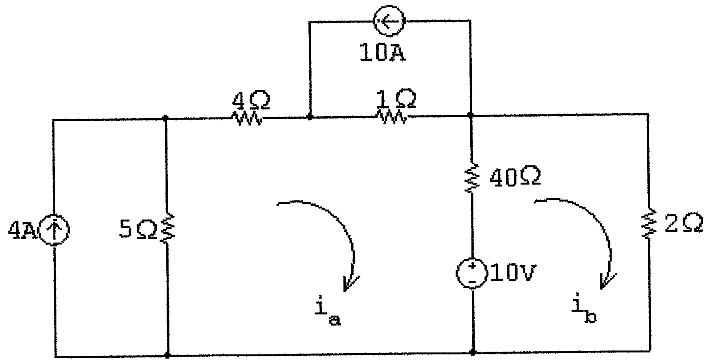


which can be reduced to



$$\therefore \quad i_o = \frac{(1.25)(8)}{10} = 1 \text{ A}$$

[b]



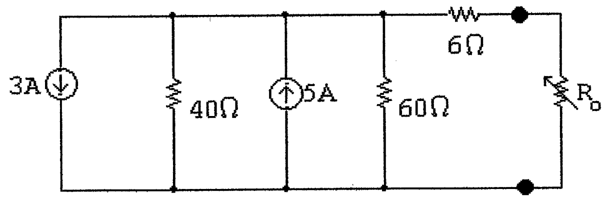
$$50i_a - 40i_b = 20 - 10 - 10 = 0$$

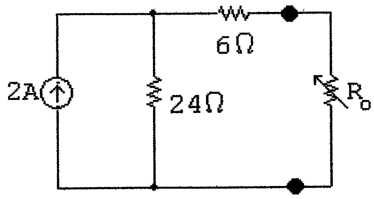
$$-40i_a + 42_b = 10$$

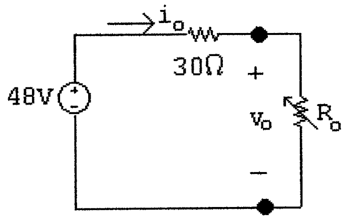
$$\text{Solving, } i_b = \frac{N_b}{\Delta} = 1 \text{ A} = i_o$$

P 4.63 $v_{Th} = \frac{60}{50}(40) = 48$ V

$$R_{Th} = 8 + \frac{(40)(10)}{50} = 16\,\Omega$$

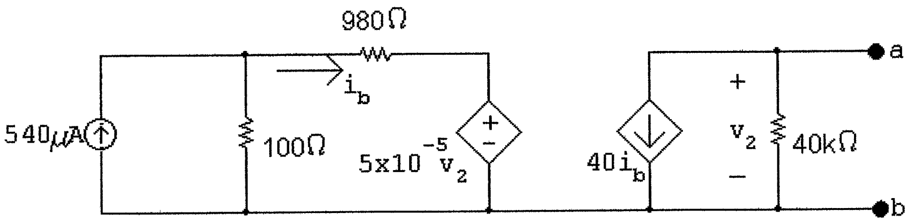






R_o	i_o	v_o	R_o	i_o	v_o
0	1.6	0	20	0.96	19.2
2	1.5	3	30	0.8	24
6	1.33	8	50	0.6	30
10	1.2	12	60	0.533	32
15	1.067	16	70	0.48	33.6

P 4.71



OPEN CIRCUIT

$v_2 = -40i_b\, 40 \times 10^3 = -16 \times 10^5 i_b$

$5 \times 10^{-5} v_2 = -80i_b$

$980i_b + 5 \times 10^{-5} v_2 = 980i_b - 80i_b = 900i_b$

So $900i_b$ is the voltage across the $100\,\Omega$ resistor.

From KCL at the top left node, $540\,\mu\text{A} = \dfrac{900i_b}{100} + i_b = 10i_b$

$$\therefore \quad i_b = \frac{540\times 10^{-6}}{10} = 54\,\mu\text{A}$$

$$v_{\text{Th}} = -16\times 10^5(54\times 10^{-6}) = -86.40\text{ V}$$

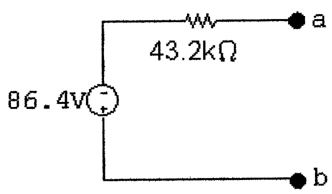
SHORT CIRCUIT

$v_2 = 0; \qquad i_{sc} = -40i_b$

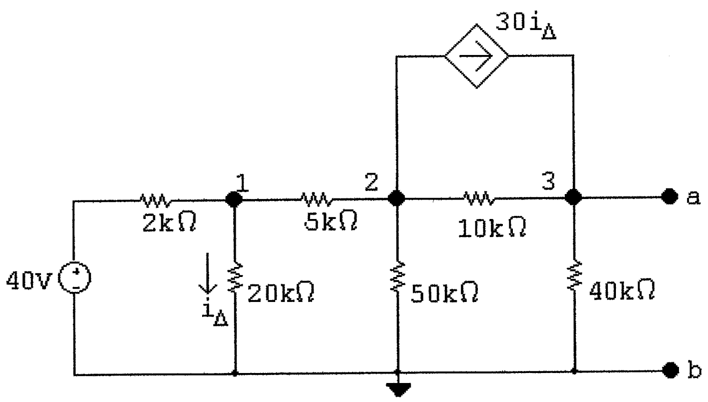
$$i_b = \frac{54\times 10^{-3}}{1080} = \frac{54}{1.08}\times 10^{-6} = 50\,\mu\text{A}$$

$$i_{sc} = -40(50) = -2000\,\mu\text{A} = -2\text{ mA}$$

$$R_{\text{Th}} = \frac{-86.4}{-2}\times 10^3 = 43.2\text{ k}\Omega$$

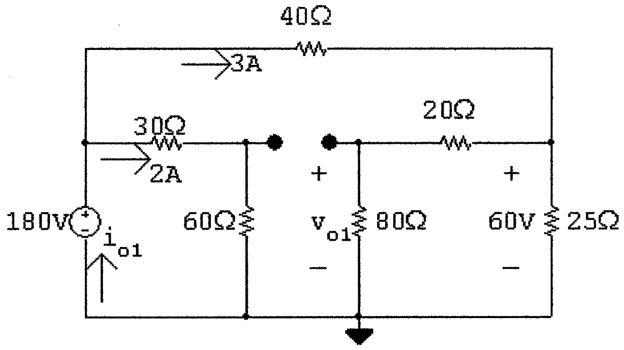


P 4.72



The node voltage equations are:

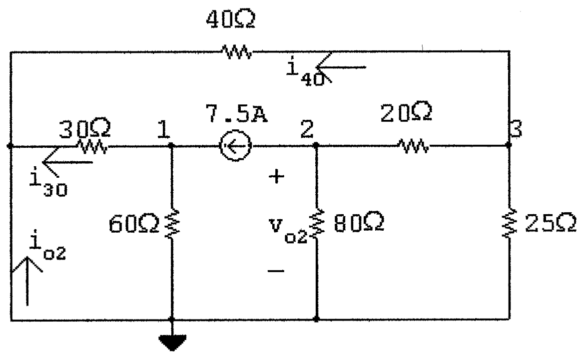
P 4.95 Voltage source acting alone:



$$i_{o1} = \frac{180}{90} + \frac{180}{40 + 100\|25} = 2 + 3 = 5 \text{ A}$$

$$v_{o1} = (3)(20)\left(\frac{80}{100}\right) = 48 \text{ V}$$

Current source acting alone:



$$\frac{v_2}{80} + 7.5 + \frac{v_2 - v_3}{20} = 0$$

$$\frac{v_3}{25} + \frac{v_3 - v_2}{20} + \frac{v_3}{40} = 0$$

Solving, $v_2 = -184 \text{ V} = v_{o2}$; $\qquad v_3 = -80 \text{ V}$

$$i_{40} = \frac{v_3}{40} = -2 \text{ A}$$

$$i_{30} = \frac{7.5(60)}{90} = 5 \text{ A}$$

$$i_{o2} = -i_{30} - i_{40} = -5 + 2 = -3 \text{ A}$$

$$\therefore \quad v_o = v_{o1} + v_{o2} = 48 - 184 = -136 \text{ V}$$

$$i_o = i_{o1} + i_{o2} = 5 - 3 = 2 \text{ A}$$