Homework # 3

P2.27* $v = 0.1\,\text{mA} \times R_w = 50\,\text{mV}$

$$R_g = \frac{50\,\text{mV}}{2\,\text{A} - 0.1\,\text{mA}} = 25\,\text{m}\Omega$$

P2.29* Combining R_2 and R_3, we have an equivalent resistance

$R_{eq} = \dfrac{1}{1/R_2 + 1/R_3} = 10\,\Omega$. Then using the voltage-division principle, we have

$v = \dfrac{R_{eq}}{R_1 + R_{eq}} \times v_s = \dfrac{10}{20+10} \times 10 = 3.333\,\text{V}$.

P2.31* At node 1 we have: $\dfrac{v_1}{20} + \dfrac{v_1 - v_2}{10} = 1$

At node 2 we have: $\dfrac{v_2}{5} + \dfrac{v_2 - v_1}{10} = 2$

In standard form the equations become

$$0.15v_1 - 0.1v_2 = 1$$
$$-0.1v_1 + 0.3v_2 = 2$$

Solving, we find $v_1 = 14.29\,\text{V}$ and $v_2 = 11.43\,\text{V}$.

Then we have $i_1 = \dfrac{v_1 - v_2}{10} = 0.2857\,A$.

P2.32* Writing a KVL equation, we have $v_1 - v_2 = 10$.

At the reference node, we write a KCL equation: $\dfrac{v_1}{5} + \dfrac{v_2}{10} = 1$.

Solving, we find $v_1 = 6.667$ and $v_2 = -3.333$.

Then, writing KCL at node 1, we have $i_s = \dfrac{v_2 - v_1}{5} - \dfrac{v_1}{5} = -3.333\,A$.

P2.36* First, we can write: $i_x = \dfrac{v_1 - v_2}{5}$.

Then, writing KCL equations at nodes 1 and 2, we have:

$$\frac{v_1}{10} + i_x = 1 \quad \text{and} \quad \frac{v_2}{20} + 0.5i_x - i_x = 0$$

Substituting for i_x and simplifying, we have

$$0.3v_1 - 0.2v_2 = 1$$
$$-0.1v_1 + 0.15v_2 = 0$$

Solving, we have $v_1 = 6$ and $v_2 = 4$.

Then, we have $i_x = \frac{v_1 - v_2}{5} = 0.4\ A$.

P2.38* $v_x = v_2 - v_1$

Writing KCL at nodes 1 and 2:

$$\frac{v_1}{5} + \frac{v_1 - 2v_x}{15} + \frac{v_1 - v_2}{10} = 1$$

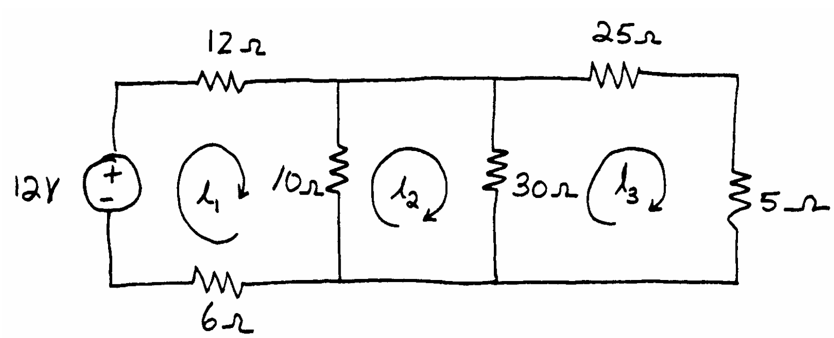
$$\frac{v_2}{5} + \frac{v_2 - 2v_x}{10} + \frac{v_2 - v_1}{10} = 2$$

Substituting and simplifying, we have

$15v_1 - 7v_2 = 30$ and $v_1 + 2v_2 = 20$.

Solving, we find $v_1 = 5.405$ and $v_2 = 7.297$.

P2.44*



Writing and simplifying the mesh-current equations, we have:

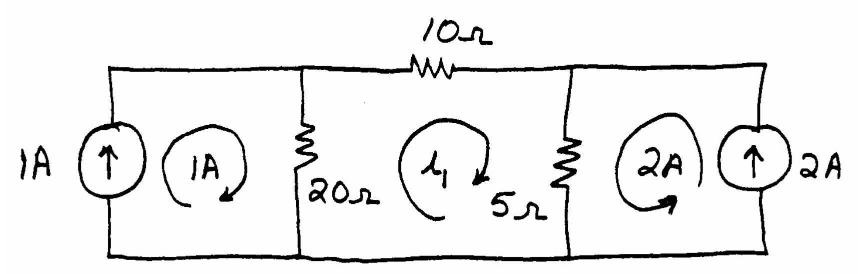
$$28i_1 - 10i_2 = 12$$
$$-10i_1 + 40i_2 - 30i_3 = 0$$
$$-30i_2 + 60i_3 = 0$$

Solving, we obtain

$i_1 = 0.500$ $i_2 = 0.200$ $i_3 = 0.100$

Thus, $v_2 = 5i_3 = 0.500\text{ V}$.

P2.48* Because of the current sources, two of the mesh currents are known.



Writing a KVL equation around the middle loop we have

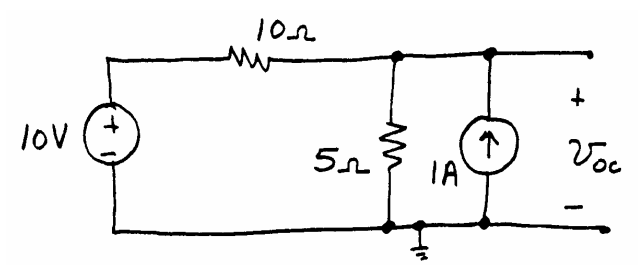
$$20(i_1 - 1) + 10i_1 + 5(i_1 + 2) = 0$$

Solving, we find $i_1 = 0.2857$.

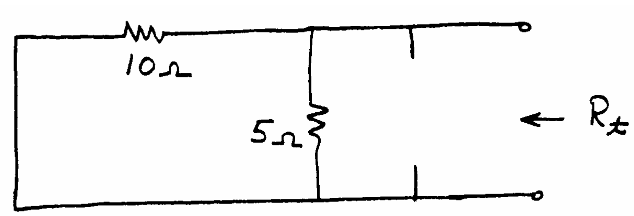
P2.51* First, we write a node voltage equation to solve for the open-circuit voltage:

$$\frac{v_{oc} - 10}{10} + \frac{v_{oc}}{5} = 1$$

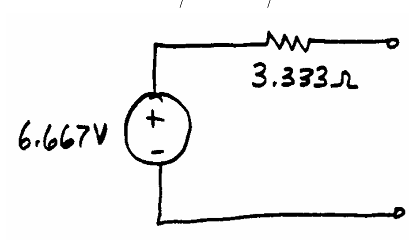
Solving, we find $v_{oc} = 6.667\text{ V}$.

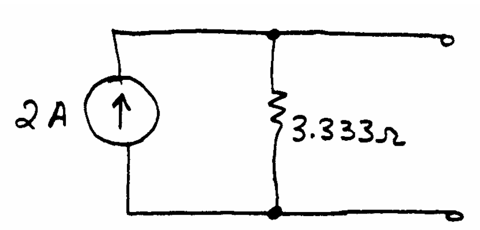


Then zeroing the sources, we have this circuit:

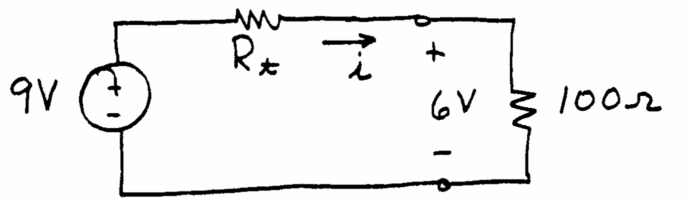


Thus, $R_t = \dfrac{1}{1/10 + 1/5} = 3.333\ \Omega$. The Thevenin and Norton equivalents are:





P2.53* The equivalent circuit of the battery with the resistance connected is

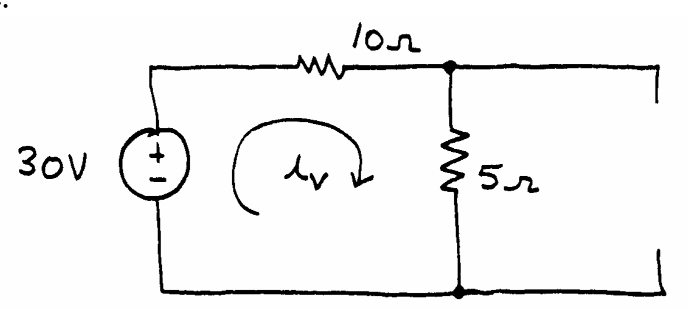


$i = 6/100 = 0.06\ A$ $\qquad R_t = \dfrac{9-6}{0.06} = 50\ \Omega$

P2.60* To maximize the power to R_L, we must maximize the voltage across it. Thus we need to have $R_t = 0$. The maximum power is

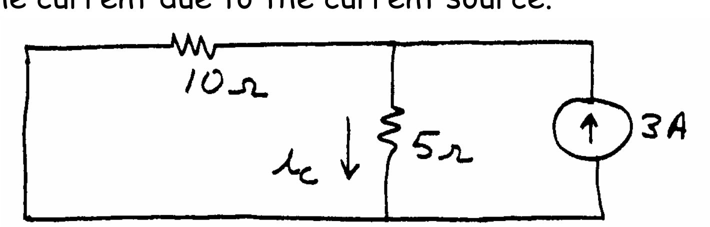
$$P_{max} = \frac{20^2}{5} = 80\ \text{W}$$

P2.63* First, we zero the current source and find the current due to the voltage source.



$i_v = 30/15 = 2\ A$

Then we zero the voltage source and use the current-division principle to find the current due to the current source.

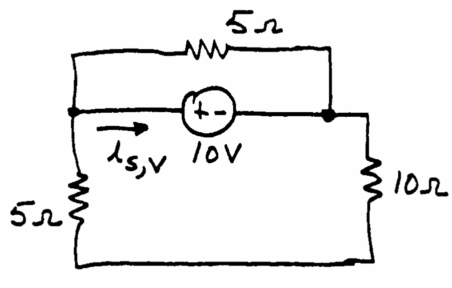


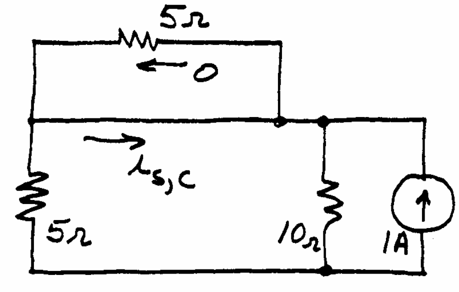
$$i_c = 3\frac{10}{5+10} = 2\ A$$

Finally, the total current is the sum of the contributions from each source.

$$i = i_v + i_c = 4\ A$$

P2.66* The circuits with only one source active at a time are:





$$R_{eq} = \frac{1}{1/5 + 1/15} = 3.75\ \Omega \qquad i_{s,c} = -1\frac{10}{10+5} = -0.667\ A$$

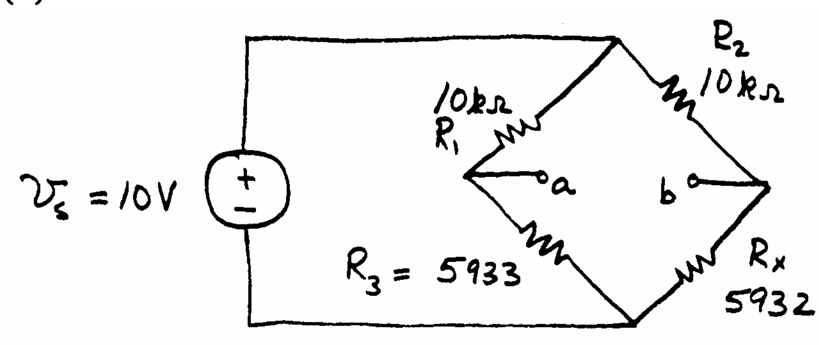
$$i_{s,v} = -\frac{10\ \text{V}}{R_{eq}} = -2.667\ A$$

Then the total current due to both sources is $i_s = i_{s,v} + i_{s,c} = -3.333\ A$.

P2.70* (a) Rearranging Equation 2.80, we have

$$R_3 = \frac{R_1}{R_2}R_x = \frac{10k\Omega}{10k\Omega} \times 5932 = 5932\ \Omega$$

(b) The circuit is:



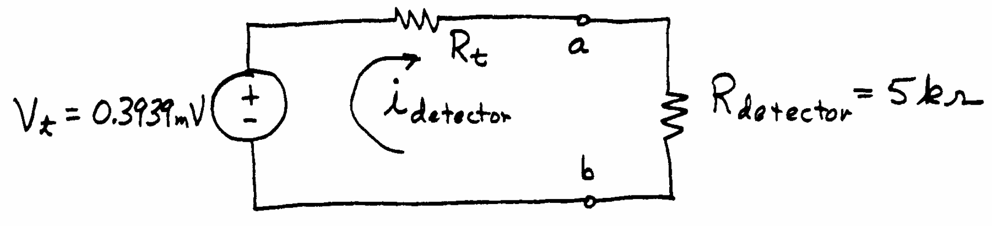
The Thevenin resistance is

$$R_t = \frac{1}{1/R_3 + 1/R_1} + \frac{1}{1/R_2 + 1/R_x} = 7447\ \Omega$$

The Thevenin voltage is

$$\begin{aligned} v_t &= v_s\frac{R_3}{R_1 + R_3} - v_s\frac{R_x}{R_x + R_2} \\ &= 0.3939\ \text{mV} \end{aligned}$$

Thus, the equivalent circuit is:



$$i_{detector} = \frac{V_t}{R_t + R_{detector}} = 31.65 \times 10^{-9}\ A$$

Thus the detector must be sensitive to very small currents if the bridge is to be accurately balanced.