1. **Equivalence** Find the Thévenin and Norton equivalents across terminals $a$ and $b$ for the circuits given below.

(a) ![Circuit Diagram](image)

$(a) V_{th} = 1.67V, I_{no} = 5mA, R_{th} = R_{no} = 333\Omega$

(b) ![Circuit Diagram](image)

$(b) V_{th} = 20,000V, I_{no} = 5A, R_{th} = R_{no} = 4000\Omega$
2. **Wheatstone Bridge** Let us revisit our favorite circuit, the wheatstone bridge. Thévenin equivalence is an alternate technique we can use to solve the bridge circuit. For the circuit below, \(R_1 = 4k\Omega, R_2 = 1k\Omega, R_3 = 3k\Omega, R_4 = 1k\Omega, \) and \(R_5 = 4k\Omega.\)

![Wheatstone Bridge Circuit Diagram](image)

(a) First, let’s for a moment remove the bridge resistor. Calculate the Thévenin equivalence between the two terminals of the resistor \(v_2\) and \(v_3.\)

**Answer:** Removing the bridge resistor, the circuit looks as follows:

![Thévenin Equivalence Circuit](image)

Notice in the above circuit, there are two voltage dividers, and we can calculate \(u_4\) and \(u_5\) quickly.

\[
u_4 = \frac{R_4}{R_1+R_4} (v_1 - v_4) = \frac{1}{1+4} (5) = 1V
\]

\[
u_5 = \frac{R_5}{R_2+R_5} (v_1 - v_4) = \frac{4}{1+4} 5 = 4V
\]

Thus the Thévenin voltage is simply the difference between the two voltages: \(u_4 - u_5 = -3V.\)

We find the Thévenin resistance by shorting the voltage source, and calculating the resistance between the two terminals.

\[
R_{th} = (R_1 || R_4) + (R_2 || R_5) \quad \text{Where} \ || \ \text{denotes the parallel operator.}
\]

\[
R_{th} = \left(\frac{4}{5}\right) + \left(\frac{2}{4}\right) = \frac{8}{5}
\]
(b) With this equivalent circuit, calculate the current through the bridge resistor.

Answer:
Know $R_{th}$, we can calculate the $I_{3k}$ by combining the bridge resistor $R_3$ and $R_{th}$.

\[ I = \frac{V}{R} = \frac{-3}{5+3} = -\frac{15}{22} mA \]

Answer:
Why were we able to remove $R_3$ when solving for this circuit, but did not remove the 4kΩ or 0.5kΩ resistors in the circuits in question 1)? The difference between the two is the purpose of the Thévenin equivalent we created. Here we are using the equivalent circuit to find the current through and voltage across $R_3$, but in problem 1), we would use the equivalent circuit to find the current through and voltage across some additional $R_{load}$ added in parallel to the resistor already there.

3. Superposition Practice

For the following circuits, use the superposition theorem to solve for the node potential $V_1$.

(a)

(b)

(c)
Answer:

(a) \((I_{S1} - I_{S2})R_1\)

(b) \(V_{S1} - V_{S2}\)

(c) First we null the voltage source and solve for \(V_{1\text{cur}}\). We see that the current gets split in two, since both branches are identical/symmetrical. This gives us \(V_{1\text{cur}} = I_S R_1/2\).

Then we remove the current source and recognize that we can simplify the circuit into a voltage divider. The total resistance of this voltage divider is \(2R_1 + (2R_2)||R_3\). Using our formula for voltage dividers, we compute \(V_{1\text{vol}} = V_S \frac{R_1}{2R_1 + (2R_2)||R_3}\).

So, \(V_1 = V_{1\text{vol}} + V_{1\text{cur}} = V_S \frac{R_1}{2R_1 + (2R_2)||R_3} + I_S R_1/2\).