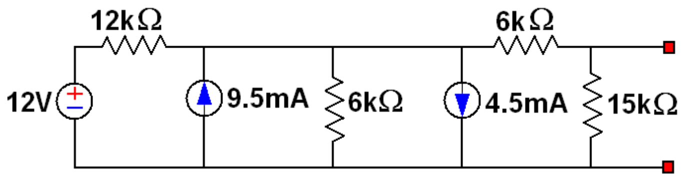
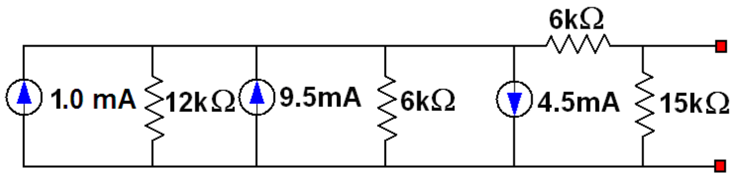
Electronics

Thevenin equivalent

Problem 1.- Find the simplest equivalent of the following circuit from the point of view of the terminals on the right side:



Solution: To simplify the circuit, let us convert the voltage source to a current source, giving the equivalent:

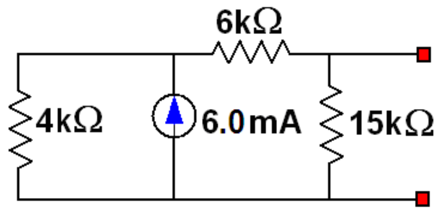


Now we can combine all the current sources that are in parallel and all the resistors in parallel on the left side of the circuit to give:

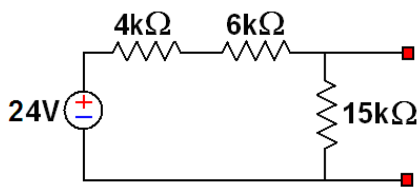
I=1.0mA+9.5mA-4.5mA=6.0mA

$$R = \frac{1}{\frac{1}{12k\Omega} + \frac{1}{6k\Omega}} = 4k\Omega$$

With these changes, the circuit looks like this:



We can go back to a voltage source, replacing the 4k-ohm resistor in parallel with the 6mA source by a 24V source in series with a 4k-ohm resistor:

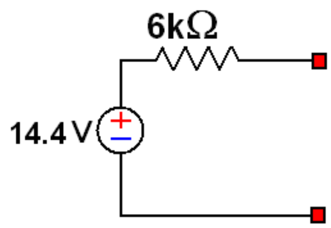


We use the rule of voltage divider to calculate the Thevenin voltage:

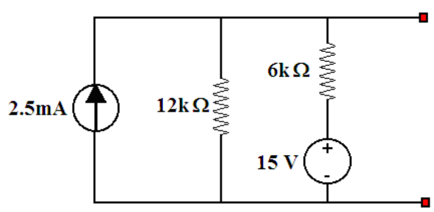
$$V_{Thevenin} = 24V\left(\frac{15k\Omega}{15k\Omega + 6k\Omega + 4k\Omega}\right) = 14.4\text{V}$$

The Thevenin resistance is obtained after replacing the voltage source by a short circuit and calculating the resistance from the point of view of the terminals:

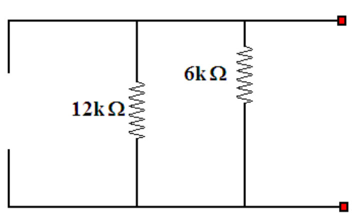
$$R_{Thevenin} = \frac{1}{\frac{1}{15k\Omega} + \frac{1}{10k\Omega}} = 6k\Omega$$



Problem 2.- Find the Thevenin equivalent of the following circuit:



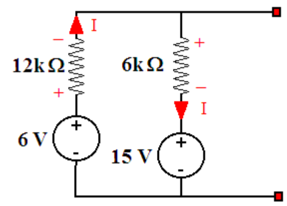
Solution: First, let us find the Thevenin resistance. We open the current sources and short the voltage sources



Obtaining

$$R_{Thevenin} = \frac{1}{\frac{1}{12k\Omega} + \frac{1}{6k\Omega}} = \mathbf{4k\Omega}$$

To get the Thevenin voltage we convert the current source in parallel with the 12kohm resistor to a voltage source with a value of 2.5mA×12kohm = 6V in series with the same resistor:



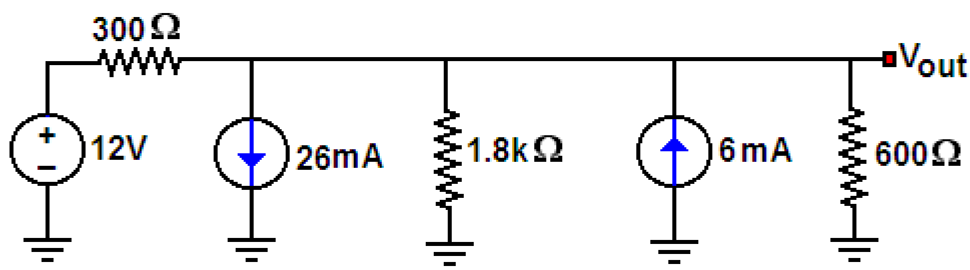
A loop equation for this circuit gives us:

$$6V - 12k\Omega I - 6k\Omega I - 15V = 0 \rightarrow I = -9V/18k\Omega = -0.5mA$$

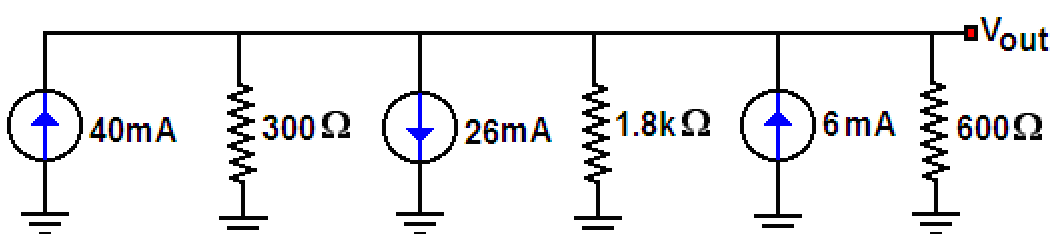
This allows us to calculate the Thevenin voltage:

$$V_{Thevenin} = 15V + 6k\Omega I = 15V + 6k\Omega(-0.5mA) = \mathbf{12V}$$

Problem 3.- Find the Thevenin equivalent of the following circuit:



Solution: We convert the voltage source to a current source, so the circuit becomes the following:



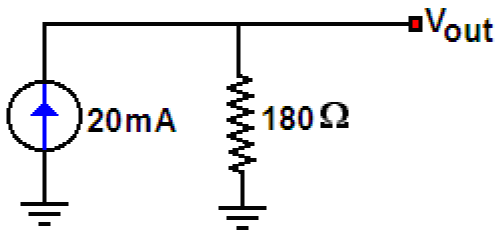
Recall that in this conversion, the resistance stays the same and the voltage source in series is replaced by a current source in parallel with a value of V/R.
The advantage of this change is that now there are three resistors in parallel whose equivalent value is:

$$R_{equivalent} = \frac{1}{\frac{1}{300\Omega} + \frac{1}{1800\Omega} + \frac{1}{600\Omega}} = 180\Omega$$

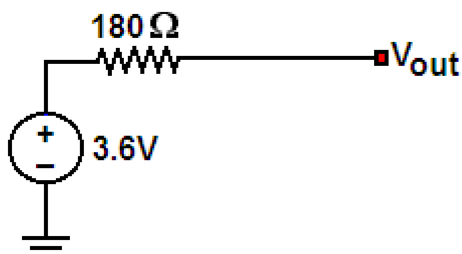
The current sources are also in parallel, so their equivalent is just one current source with the sum of their currents (considering their orientation).

$$I_{equivalent} = 40mA - 26mA + 6mA = 20mA$$

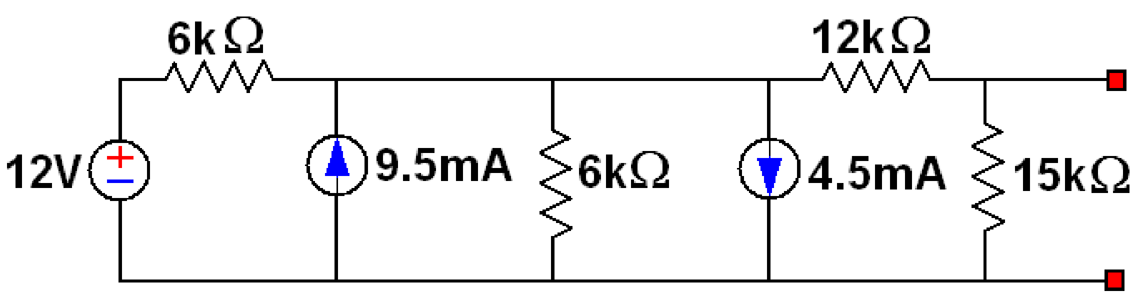
So the equivalent circuit becomes:



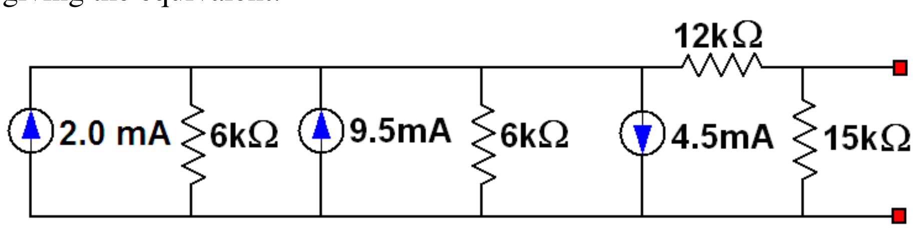
This circuit can also be converted to a Thevenin equivalent by keeping the same resistance and replacing the current source by a voltage source of value RI, as follows:



Problem 4.- Find the simplest equivalent of the following circuit:



Solution: Similar to what was done above, let us convert the voltage source to a current source, giving the equivalent:

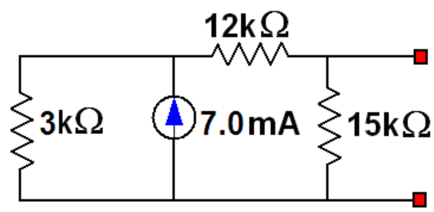


Now we can combine all the current sources and all the resistors in parallel to give:

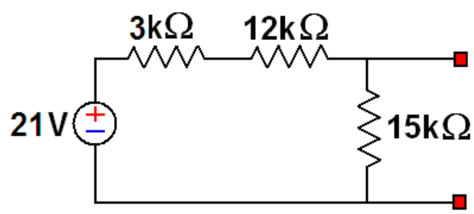
I=2.0mA+9.5mA-4.5mA=7.0mA

$$R = \frac{1}{\frac{1}{6k\Omega} + \frac{1}{6k\Omega}} = 3k\Omega$$

With these changes, the circuit looks like this:



We go back to a voltage source, replacing the 3k-ohm resistor in parallel with the 7mA source by a 21V source in series with a 3kohm resistor, to get:



The Thevenin voltage is calculated using the rule of a voltage divider:

$$V_{Thevenin} = 21V\left(\frac{15k\Omega}{15k\Omega + 12k\Omega + 3k\Omega}\right) = 10.5\text{V}$$

And the Thevenin resistance is obtained after replacing the voltage source by a short circuit:

$$R_{Thevenin} = \frac{1}{\frac{1}{15k\Omega} + \frac{1}{15k\Omega}} = 7.5k\Omega$$

Giving the final equivalent circuit: