Class Problem - Thevenin Equivalent Circuits

Obj: to demonstrate that the Thevenin equivalent circuit is dependant upon which terminals, or nodes, you specify as the output nodes.

Circuit

\[
\begin{array}{c}
\text{24V} \\
2\Omega \\
\end{array}
\begin{array}{c}
\text{\[3\Omega\]} \\
\text{\[4\Omega\]} \\
\text{\[5\Omega\]} \\
\end{array}
\begin{array}{c}
a \\
b \\
c \\
\end{array}
\begin{array}{c}
\text{\[1\Omega\]} \\
\text{\[2A\]} \\
\end{array}
\]

(a) Specifying terminals a-b as the output terminals. This means that "b" is the ground, or 0V node, in this situation.

Find \(R_{eq}\): zero out sources.

1. Find \(R_{eq}\) from "a" to "b".

\[\begin{align*}
\text{Req} &= 1 + \frac{(3+2+5)}{4} \\
&= 1 + \frac{10}{4} \\
&= 1 + 2.5 \\
&= 3.5 \Omega
\end{align*}\]

2. Find \(V_{th}\): replace all sources, to return to original circuit.

- Identify which voltage = \(V_{th}\).
- Find that voltage using all/any circuit analysis techniques that is useful.
(Thevenin example)

- As required for this method (finding a Thevenin equivalent circuit), you must have an open circuit across the specified output terminals ("a"-"b" for now).

- This means no current flows at the output terminals.

- So, for this example, no current flows through the 1 \( \Omega \) resistor.

- Therefore, there is no voltage difference across the 1 \( \Omega \) resistor.

- So, \( V_{th} = V_{ab} = V\text{ across the } 4 \Omega \).

Finding \( V_{th} \)

Using mesh analysis:

KVL:

\[ 2I_1 - 24 + 3I_1 + 4I_1 + 5(I_1 + I_2) = 0 \]

\[ 14I_1 - 24 + 10 = 0 \]

\[ 14I_1 = 14 \text{ so } I_1 = 1A \]

Ohm's law for the \( 4 \Omega \) resistor, which shares our output nodes (since \( I_o = 0 \)):

\[ V_{th} = I_1 R = (1A)(4\Omega) = 4 V \]

*Final Thevenin equivalent circuit*

This means a load connected to terminals "a-b" above, or to the equivalent at left, will not be able to distinguish between them.
Thevenin equivalent for terminals b-c

\[ R_{TH} = 4 \Omega \]

\[ \text{current } = 0 \text{ on this open branch} \]

Being an election that is traveling from "b" to "c", you would immediately encounter a branching or forking path at the red dot. Hmm, to go through the 4Ω resistor or the 5Ω resistor? But wait, the 4Ω is in series with a 3Ω + 2Ω, so in fact the decision is between a 5Ω and an equivalent of (4+3+2)Ω.

Flowing along these two branches, you would find they come back together at the common node with the green circle. These branches share 2 nodes: o & o

This means the 5Ω is in parallel with (4+3+2)Ω branch

\[ R_{eq} = \left( \frac{1}{5} + \frac{1}{4+3+2} \right)^{-1} = 3.2 \Omega \]

\[ V_{TH_{b-c}} \]

The circuit analysis is the same as for \( V_{TH_{a-b}} \), except now you need to identify which voltage drop = \( V_{TH_{b-c}} \).

This is the same as the voltage across the 5Ω due to the 2A source. Using Ohm's Law for the 5Ω resistor we find \( V_{TH} = IR = (I + I)5 = (1+2)5 = 15V \)

\[ 15V \]