Electronic Instrumentation

Name _______________ ENGR-4300 Fall 2000 Section ____________

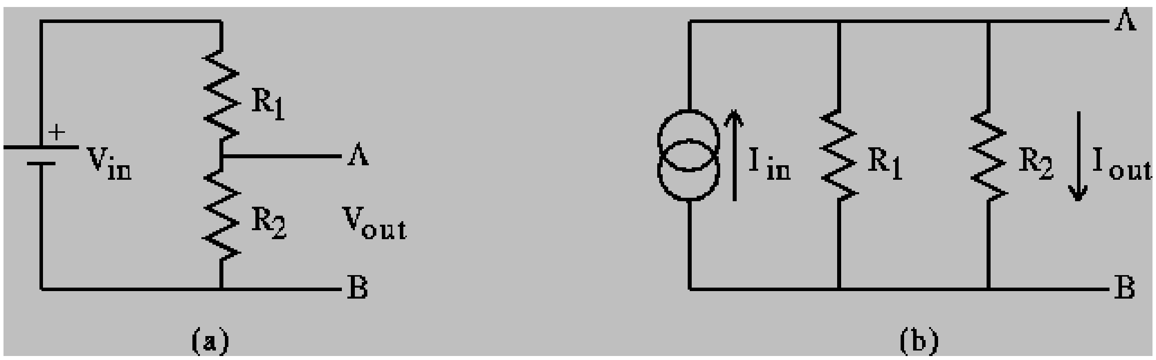
Homework #1 *(Revised 14 September)*

Thevenin and Norton Equivalent Circuits

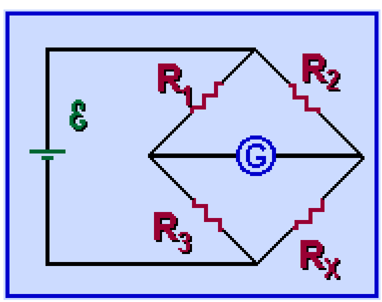
Due: 15 September

We will not be doing a great deal of pencil and paper circuit analysis in this course. We will be relying on PSpice to determine voltages and currents for most of the circuits we will study. However, there are a few basic configurations we will need to understand a little bit better. The only way to obtain this higher level of understanding is to do the analysis ourselves.

We have already seen voltage dividers under several different circumstances. There is also a circuit called a current divider, which we will also need to understand, but not right now. These two dividers are shown in the figure below, which is taken from page 10 of Gingrich. The voltage divider is also found on page 5 of the Engineer's Mini-Notebook on Formulas, Tables and Basic Circuits.

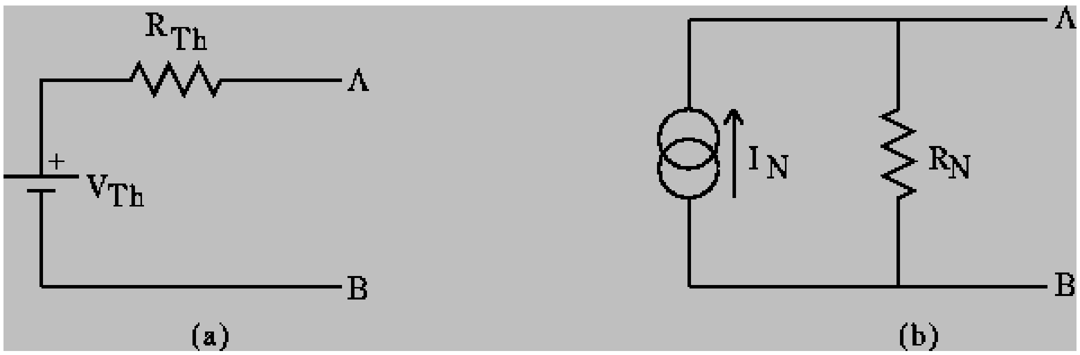


Another circuit we have seen in experiments 2 and 3 is a combination of two voltage dividers, which is called a bridge circuit. Actually it is called a Wheatstone Bridge, but we mostly forget about Mr. Wheatstone when we talk about it. There is some good basic info on circuits to be found on many, many different pages on the web. One of these sites is at the University of Guelph where you can find tutorials on such topics as DC circuits at http://www.physics.uoguelph.ca/tutorials/ohm/Q.ohm.html



In this figure, taken from the Guelph tutorial, the capital E represents the voltage source (this letter is used a lot, but not as much as the capital letter V), and G represents some kind of measurement device. This circuit has been set up to determine the unknown resistor R_x, just as we did in Experiment 2.

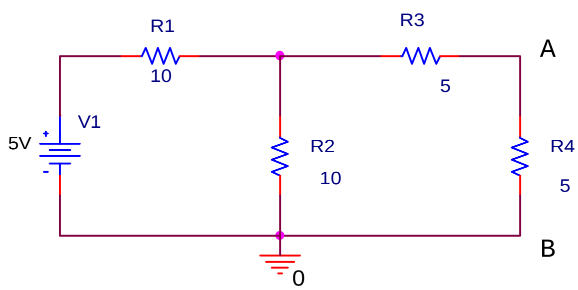
When we use such circuits as voltage dividers or bridges to produce a voltage of some kind, we will be using them like a voltage source. We have seen that voltage sources such as our function generator, a battery, etc. all have an internal resistance of some kind. We, therefore, can expect to require similar information about dividers or bridges when we use them as sources. It turns out that any combination of voltage or current sources and resistors can be simplified into one of the two following forms, called Thevenin and Norton Equivalents.



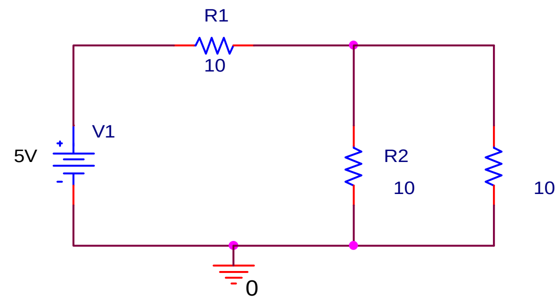
We will only be concerned with the Thevenin equivalent for now. Note that this simple combination is the model we have used for the practical sources we have seen in the studio.

Read section 1.4 of Gingrich, in which he discusses Equivalent Circuits. He does a relatively thorough example finding the Thevenin voltage and resistances for a bridge circuit. We can generalize his result for resistors labeled R_1, R_2, R_3, R_X as in the circuit from Guelph. That is, we can determine both V_{Th} and R_{Th}. We can also find the Thevenin voltage and resistance for the voltage divider circuit on page 5 of the Mini-Notebook on Formulas, Tables and Basic Circuits. These questions were asked last semester, so their answers can be found in the *Class Reserves* – which can be accessed using a link at the top of the course *Syllabus* webpage.

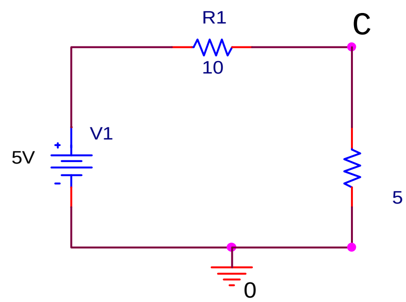
Once you have looked over Gingrich and the solution to the homework from last semester, determine V_{Th} and R_{Th} for the following circuit. Assume that the output is taken across the points labeled A and B.



Ans: To determine the voltage at point A relative to point B (ground), it is first necessary to determine the voltage at the unmarked point above resistor R2. To do this, we first combine R3 and R4 is series to obtain 10ohms.

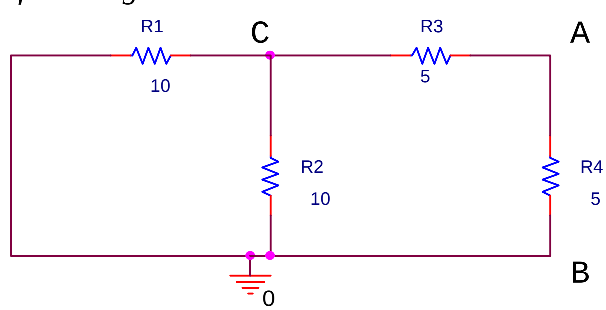


Then we add this 10ohm resistor in parallel with R2 to obtain 5ohms. Recall that the parallel combination of two identical resistors is equal to half of each resistor.

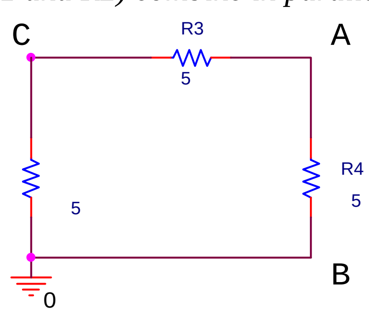


Now we have a simple voltage divider and the voltage at point C is 5/3. The voltage at point A is half of the voltage at C or 5/6 volt.

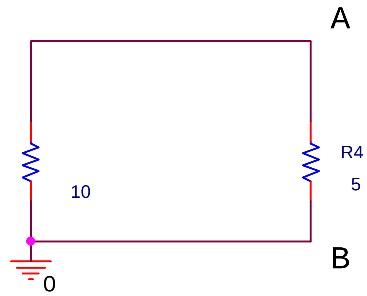
To determine the Thevenin resistance, the simplest method is to short out the voltage source to produce the following circuit:



The two resistors at the left (R1 and R2) combine in parallel to become 5 ohms.

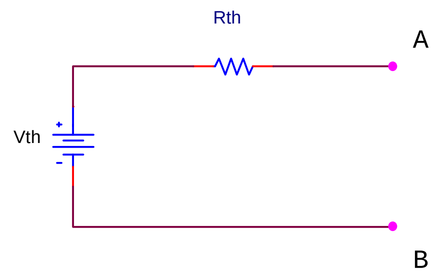


Then, add this 5 ohms in series with R3 to obtain 10 ohms. We then have 10 ohms in parallel with 5 ohms.

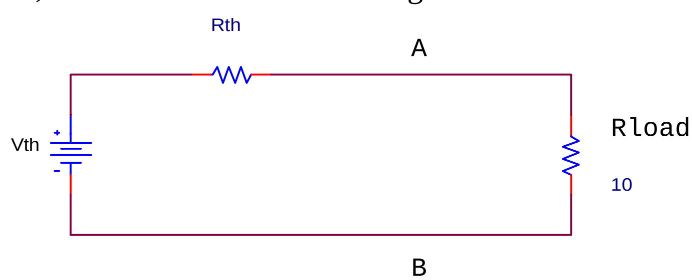


This parallel combination results in a net resistance of 3.333 ohms.

Now you can simplify this circuit to look like the following:



Then use your Thevenin equivalent source to find the voltage that would appear across a 10ohm resistor connected between points A and B. Once you connect this additional resistor to the circuit, it will look like the following:



Ans: The voltage divider action for give the voltage across the load as

$$V_{LOAD} = V_{TH}\frac{10}{10+R_{TH}} = \frac{5}{6}\frac{10}{10+3.333} = 0.625 volt$$

*This assignment **mostly** requires you to review what you have seen previously with respect to voltage dividers and bridges. However, you will need to understand the method by which the Thevenin resistance is determined. We will discuss this in class and you can read about it in Gingrich. To find Thevenin equivalent circuits, you must also be able to readily analyze series and parallel combinations of resistors and, ultimately, other kinds of impedances. To check to be sure that you have developed your skills adequately, you should visit the **Precision Teaching – Electromagnetics** site at Georgia Tech and download Unit 5 (Resistors in Series/Parallel, RC Circuits, Kirchoff's Laws). You can download all of the units if you wish, but this is the only one we will need for this course. Once you think you understand series/parallel combination of resistors and Kirchoff's Laws, give yourself the tests, but address only the questions involving resistors and voltage sources, not capacitors. The capacitor problems should be tried after we introduce them. It is very important that you go through the relevant tests in this unit before Quiz 1, since mastering these skills will make taking this quiz a lot easier. Note – if you do not have a* *computer of your own, please use the available open shop time to do these tests using the studio computers.*