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ENGT 279

Capstone Paper

Complex Circuits Analysis

This paper will primarily focus on solving network circuits using two different methods, assumed loop or mesh current analysis, and nodal analysis, both of which are different approaches to solving complex circuits using one or more sources. The purpose of this paper is to both give an overview of what these methods are, how they work, and how to apply them to real problems and show solutions in both a pure equation form and in multisim, in a pictorial with explanations of the methods given in written form. Along with this, this paper also helps to hone my skills in an area in which was difficult, and potentially help others who decide to take a course like circuits analysis.

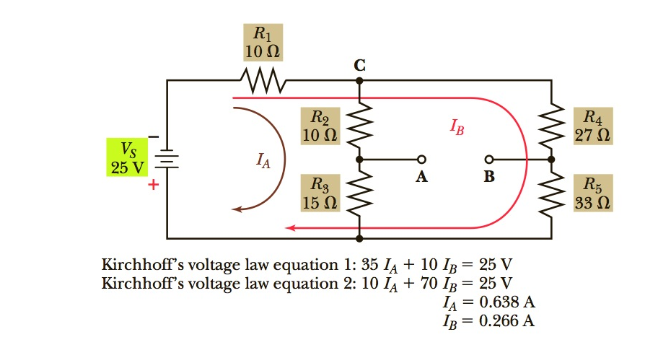
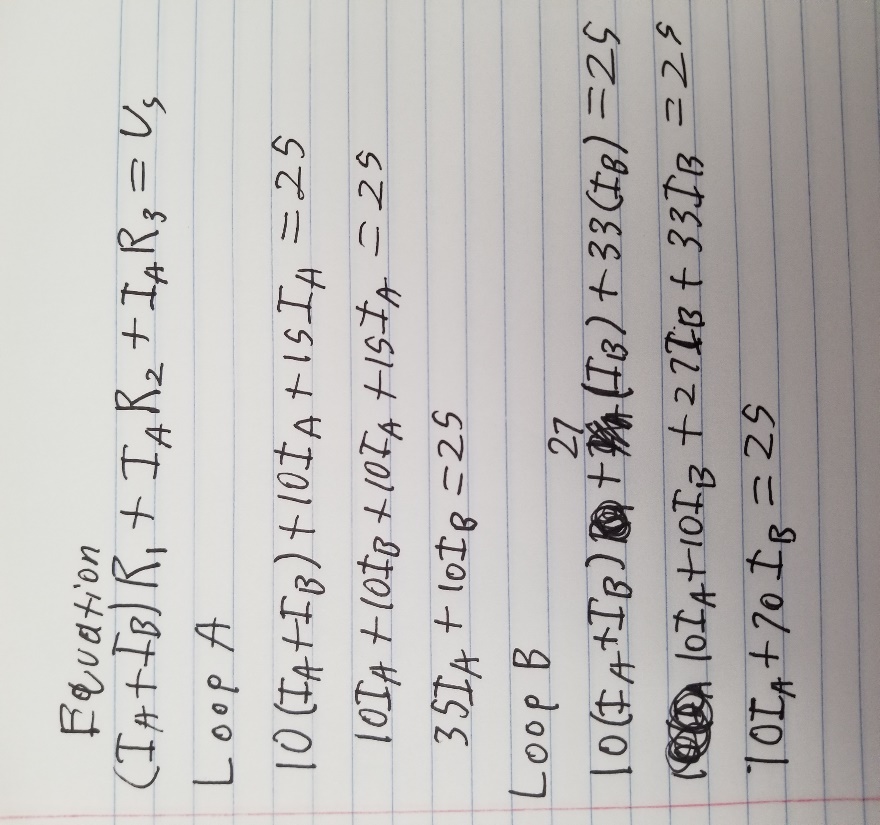
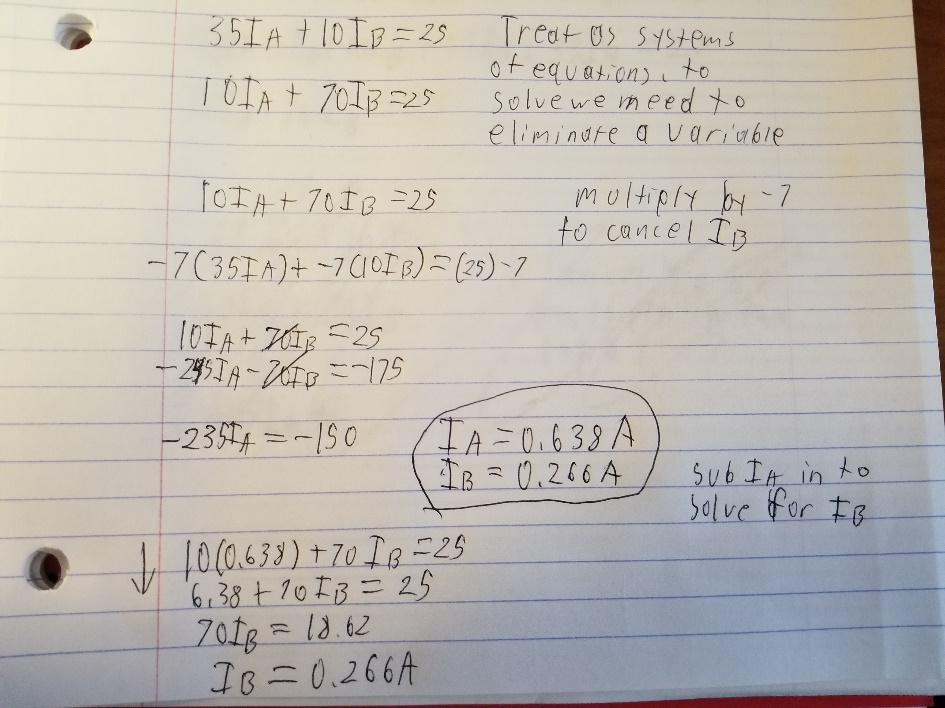
The first of the methods is called assumed loop, or mesh current analysis. This term mesh, comes from the way a screen door mesh looks, with the wires in the screen being the wires in the circuit with gaps in between. This method starts off by looking at the circuit and drawing in loops that outline the flow of the current for each mesh in the circuit. This is done to break down the circuit into smaller pieces to make analysis easier. After breaking down the circuit down into smaller meshes, it is helpful and good practice to identify easy meshes and write the equations for them first. For example, in the picture down below, sourced from the textbook, it shows how one might break up a circuit into different loops, or meshes, then using Kirchhoff’s current law, write the equations for each mesh. When using this method, it’s also important to keep track of the polarity across each resistor, so that when we do our calculations, they have the right sign. This is the only major pitfall that I could really identify with this approach that could be a potential pitfall when looking at these types of problems. When looking at current going through a mesh, you should assume that any voltage drop created by the same mesh that you are looking at to be positive, whereas any voltage drop created by another mesh is going to be negative, and that is due to the current in each mesh being assumed to be going in a clockwise direction. Looking at the example, we see that in the first loop, Ia, we have the 35 ohms added up, then we add that to the 10 ohms from current Ib that passes through that same first resistor. Then in the second mesh, we have the 10 ohms from the first resistor, along with the 27 ohms and 33 ohms for a total of 70 ohms for current Ib, being added to the 10 ohms from current Ia. Then we plug everything into Kirchhoff’s equation for each loop, which means we have two different equations to solve. In the work shown to the left, I have simplified them to their base forms using Kirchhoff’s current laws. Doing this allows us to get both of our equations into a form that we can use to actually solve for our unknowns, Ia and Ib. We do this by treating it like a systems of equations problem, and solve for one of our unknowns, then we use that value to solve for our other unknown.

Figure 1

Figure 2

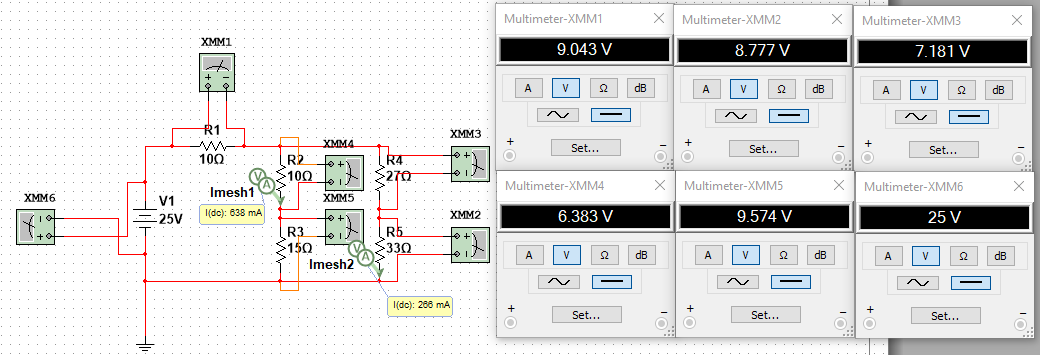
As shown in the worked example in the left, multiplying the top equation by negative 7 allows for the cancelation of Ib, giving the ability to solve for the value of Ia. After solving for these two currents, that gives us both of our currents in that circuit. This gives us the ability to use ohms law in order to find the voltage drop at any point in the circuit through V=IR. We can also check our work by using the voltage drops around the circuit and adding them together to ensure that we get 25V all around. This method outlined above can also be proven using multisim to create the circuit and verify that the answers that were calculated are correct. Setting the circuit up and making sure to ground the circuit correctly we can use multimeters to get the voltage drops going through each of the resistors, as well as using it to make sure that the amperage calculations are correct. This work is shown in Figure 4, but it is worth noting that this was done using a simulation and thus is inherently flawed, which as I will explain has several issues with that approach.

Figure 3

Figure 4

The example in the previous page is the circuit set up in multisim, proving that the work done using the theory and arithmetic is sound, that being that the simulation backs up the calculations. Worth taking into consideration is that the numbers in both the multisim and in the raw calculations are based on a perfect world, that meaning that if this circuit was made using actual parts, the numbers would be off the “perfect world” calculations and simulations. This in a nutshell basically means that you will almost never be able to replicate these results in the real world, as each component that you will use to create, measure, and otherwise construct the circuit will be off in some way or another. This is something that in every lab that was completed in the circuits analysis class, as well as any attempt to replicate in real life will never completely line up, however using a percent error equation you can, if it so pleases you or is required, figure out how much discrepancy there is between the real world and the simulation, and in between the calculations and the real world.

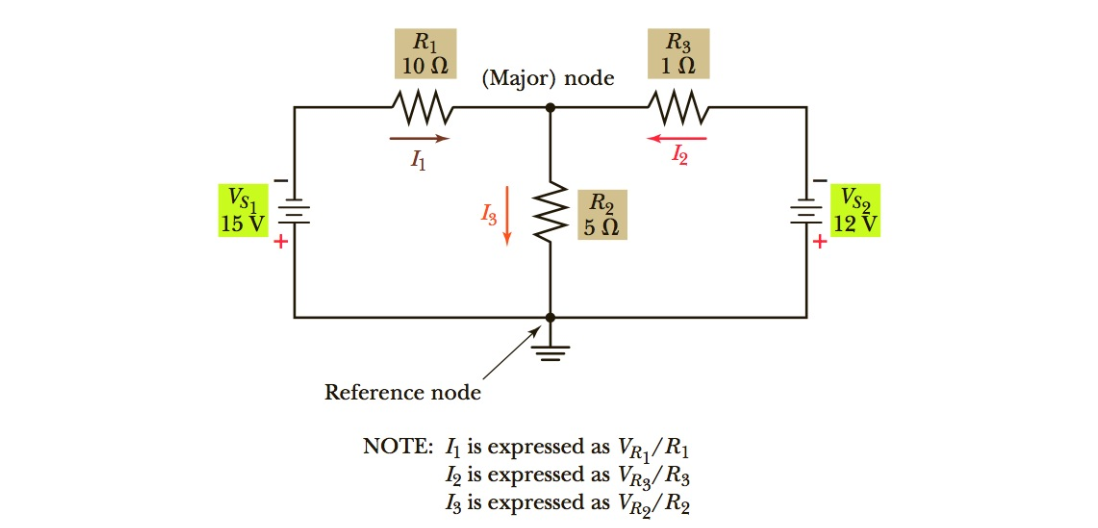
Nodule analysis works using Kirchhoff’s laws at its core like mesh analysis but defines the points at which we start and how the circuit is broken up in a very different way. However first defining exactly what the definition of a node is probably is a better way to start off. A node is simply put a current junction point, or a point where currents enter and leave. This form looks at the circuits as a system of nodes, one of them being a reference node, and then any point which has several components involved are defined as major nodes. The analysis starts by selecting one of the nodes as a so called “reference node”, usually and preferably a node that s common to as many parts of the network as possible. After designating the reference node, voltages for every other node are then specified, with these voltages being relative to the reference node. After that is done, a Kirchhoff’s current equation is created for every node other then the reference node. Keep in mind that the nodes that you are writing these equations for are the major nodes in the network. Another good tip is that the number of equations that are generally required are one less then the number of major nodes. After that is done, you then incorporate the known vales of voltage and resistance in each of the equations and solve through each of them. Based off these results, you then solve for the voltage values and current for each of the components. In Figure 5 included below, you can see the way that the circuit is divided up into nodes, as well as the currents, IE I1, I2, and I3 are being defined.

Figure 5

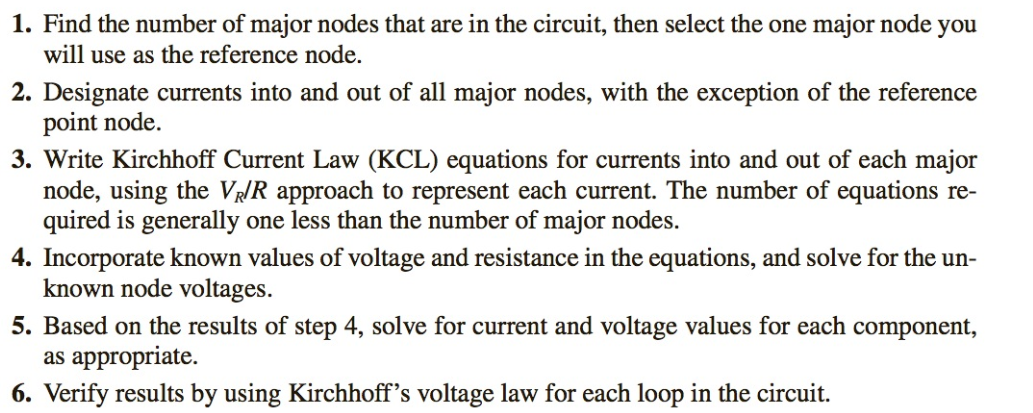
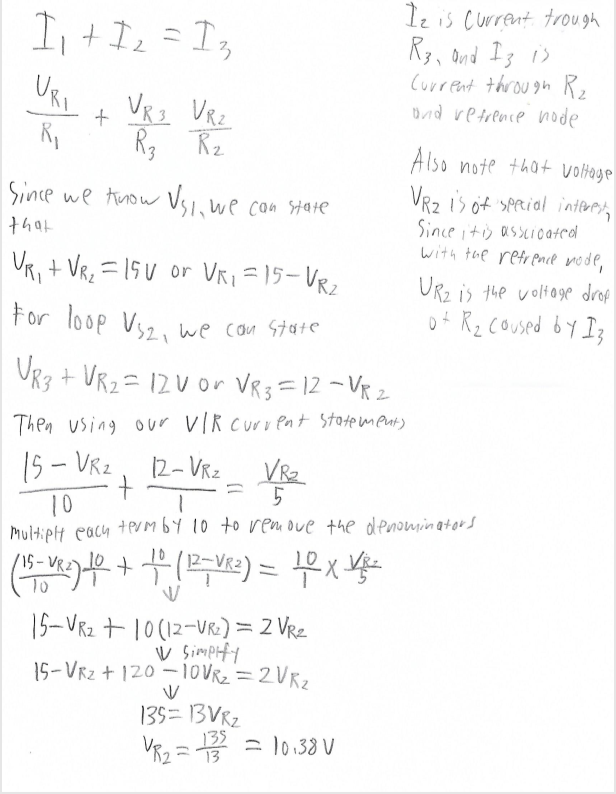
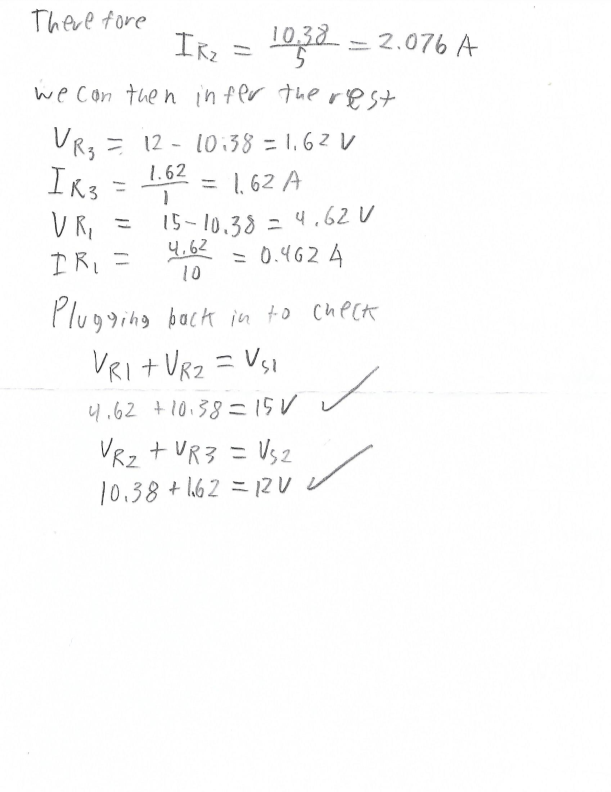
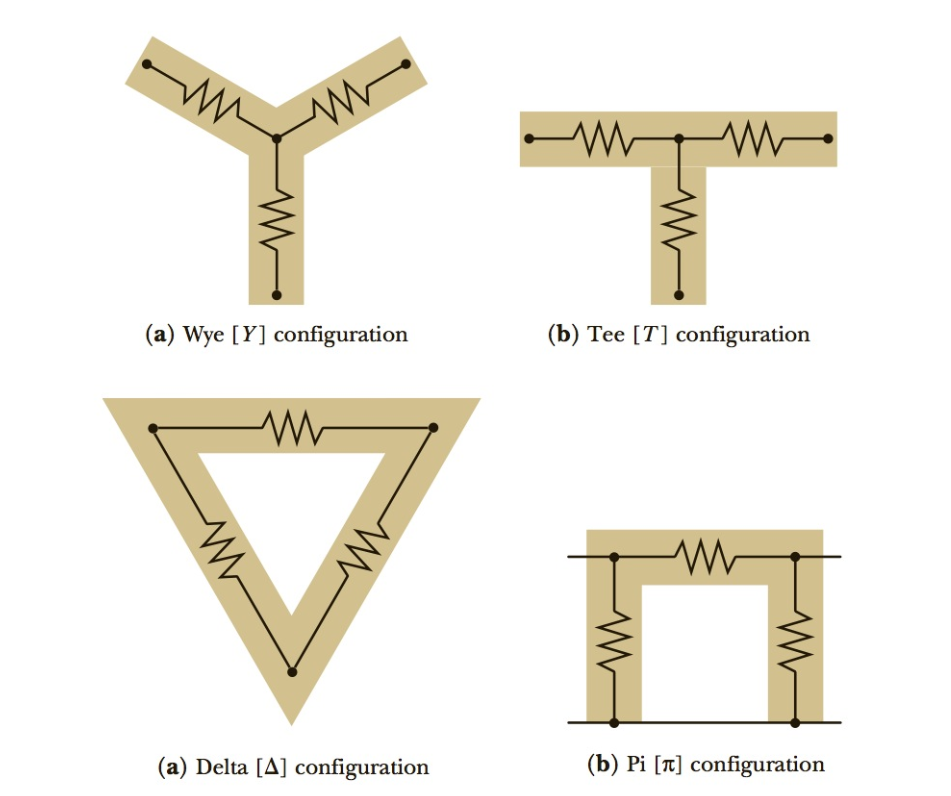
 This method relies on using a relative value, so the main focus will be on getting the voltage passing through that node first, that node being the voltage drop across resistor two, or R2. Once we have that node we can then use that through Ohms law to calculate our remaining values. This is the value of this particular method, however if I may add a personal opinion, this method was much harder to both understand and employ then the mesh method, and that would be my personal method of choice in almost any circumstance. The main reason for this being my personal difficulty in understanding in how to break up the circuit. Understanding of the principle of taking a node as a reference node and treating all the other relevant nodes as major nodes is simple enough, and drawing the diagram is not so bad. Past this however, understanding how exactly to set up the equations is something that took some work to understand, hence the thinking that the mesh method of analysis is more initiative and easier to pick up and understand. However, this method allows for the calculation of all of the needed variables using very little information, just the voltages and the resistance of each resistor, and is also an interesting way to solve this type of circuit. On the following page you will see Figure 6, showing the calculations employed to solve this circuit, as well as any information that was helpful to keep in mind. Also included in Figure 6 is an excerpt from the text book of a general flow chart that can aid in understanding.

Figure 6





As the previous pages show, going through the steps of nodal analysis work different then the mesh network method of analysis, but gets you pretty much the same information. The truly useful part of this method is it makes unwieldly numbers easier to work with. However, it for me at least was a harder method to work with because the way you handle it is more abstract then drawing your loops and solving in that manner as in the mesh method.

 The last topic covered was the conversion that work on specific configurations of networks and the equations that represent them. These networks are Delta, Wye, Tee and Pi networks, and are so names because they look like those Greek constants. The main use of these conversions is in the analysis of a bridge network. Figure 7 shows some of the more common configs foe these types of networks, as well as the type each of them is, while figure 8 shows the delta network set up and labeled properly

Figure

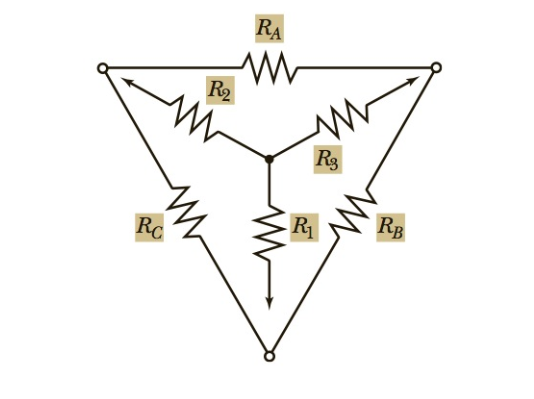
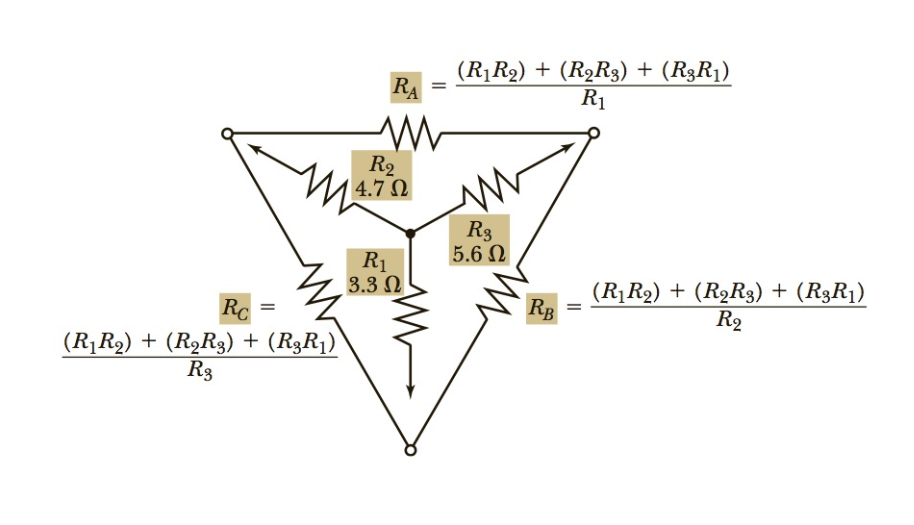
As Figure 8 on the left shows, in a clockwise manner on the middle bottom resistor they are labeled R1, R2 and R3 respectively, and the opposite was done on the outer resistors. This labeling makes our equations easier to work with and makes it more clear what resistors we are talking about. The main objective of all of this is to create and set the circuit up so that the components provide the same electrical load as the original Wye network. Figure 9 shows each of the equations set up and what part of the network they correspond to. This shows that the math is pretty simple compared to some of the analysis that was done earlier in the chapter. Note that the numerator of all of the equations is all the same, and consists of the values of the internal resistors, these are then related over a fraction to a corresponding outer resistor.

Figure 9

Figure

If we followed these equations, we would find that Ra is equal to 60.31/3.3 and taking that fraction all the way through Ra is 18.28 Ohms. However, the number of interest is that 60.31, which when taking with the other two resistors the same way, with the resistor in the denominator, gives Rb and Rc. This is the base way that all of these circuits are treated and all of them can be solved using similar methods.

These strategies for looking at different ways of analyzing networks have been a good way to brush up on and batter understand a course that was in all honestly pretty challenging. It pushed me to think in a different way, and to see the equations, methods, and strategies that I was being taught as not just simple problems to solve and move on, but for what they actually are, tools in a tool box to allow me to expand what I can do in a given field. That’s the true take away form not only this chapter or even this course, but from my time at Ivy Tech. I may not remember every single thing that I went through in all of my courses, but I did learn how to problem solve, and that is one of the most important lessons of all.