Kirchoffs Current Law (KCL)

Kirchoff's current law (KCL) states that the algebraic sum of branch currents flowing into and out of a node is equal to zero. This is an outcome of the principle of the conservation of electric charge. If any new charge enters a node some equal amount of charge must exit. The term "algebraic sum" indicates that the summation takes place with regards to the signs of the individual quantities.

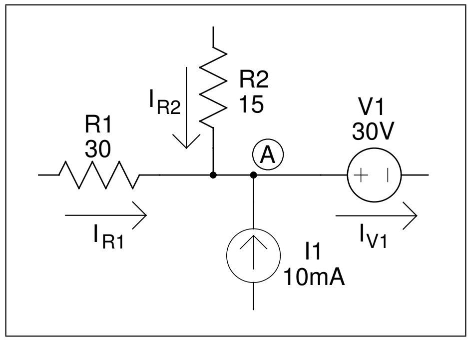

Figure 1: Currents Summing at Node A

At node A, we can say:

$$I_{R1} + I_{R2} + 0.01 - I_{V1} = 0 \tag{1}$$

When summing currents at a node, we choose which direction (flowing in or out) is *positive*. This is merely reference direction, not an absolute direction. In the example above, currents flowing into node A are assumed positive, those flowing outwards are assumed negative. This allows us to wire the KCL equation at A as above. We do know for sure that I_1 is flowing into the node and is a positive 10ma. I_{R1}, I_{R2}. and I_{V1}, may or may not be flowing in their assigned directions.

We can also think of KCL in terms of a water analogy. Water, like charge cannot accumulate at a point in a pipe. At the junction of several pipes, it is clear that the number of gallons per second of water entering the pipes must equal the number of gallons of water leaving the pipes.

Or most succinctly, in terms of "n" branch currents:

$$\sum_{n=1}^{N} I_n = 0 \tag{2}$$

Kirchoff's Current Law is also known as nodal analysis. It is the easiest method to apply for solving complex circuits. Suppose we have the circuit below. How many loops are there? Which loops do you use to solve for currents or voltages?

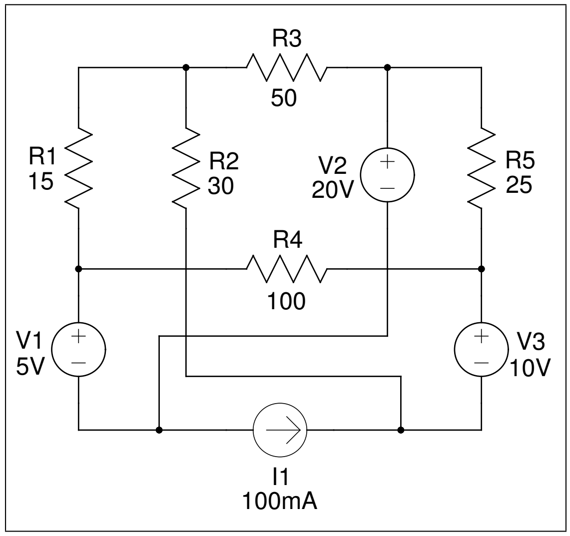

Figure 2: Circuit Forming a Non-planar Graph.

To allow us to easily solve for the voltages and currents, we want the set of independent simultaneous equations with the least number of variables. A set of equations are linearly dependent when at least one of the equations can be expressed as a linear combination of the others. For example:

$$3I_1 + 2I_2 - I_3 = 4 \tag{3}$$

$$-I_1 + 5I_2 + 3I_3 = -2 \tag{4}$$

$$I_1 + 12I_2 + 5I_3 = 0 \tag{5}$$

Equation 5 may be obtained by multiplying equation 2 by 2 and adding equation 1 to it. Thus no unique solution for I_1, I_2 or I_3 may be found. The nodal analysis method usually gives us a smaller set of variables (nodes) by which we can find a set of independent equations quickly. Spice (a circuit simulator) uses this method to solve circuits.