PRE-LAB #3: Kirchhoff’s Circuit Laws

The Interpretation of Basic Circuit Laws

In 1845, Gustav Kirchhoff, partially working from Ohm’s discovery, formulated two more mathematical theories. These are known as Kirchhoff’s Laws and they drastically aid our understanding of circuits. As we begin our own exploration of electronics, we will re-investigate these fundamental laws of circuit theory ourselves.

Ohm’s law may be used to describe a very simple circuit with only a single source and a single resistor. When two resistances are connected across the same voltage drop (such as the second schematic of Figure 1), there are in fact two paths for the current to flow from the positive terminal of the source to the negative terminal. In this configuration, the two resistances are said to be connected in parallel. It is sometimes beneficial to think of resistors as pipes. The narrower the pipe, the larger the resistance to current flow. Having two resistances in parallel is similar to adding an extra pipe for the water to follow compared to the single resistor configuration. In the analogy, water would flow through both pipes, but more water would flow through the wider pipe as it offers less resistance to flow.

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\begin{align*}
\text{Figure 1: Two circuit schematics used to explore current in parallel resistive elements. In (a), the current has one path back to the source. In (b), the current has two parallel paths back to the source.}
\end{align*}
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**Question 1:** Assume $R_1$ is the same value in both Figure 2 (a) and (b). Then the current $I_2$ will be larger than $I_1$. Explain this fact using both Ohm’s law and the water-pipe analogy.

**Question 2:** Given that $R_1 = R_2$, how do $I_3$ and $I_4$ relate to one another? Is one greater than the other? How do they each relate to $I_1$? Explain your reasoning using Ohm’s Law.

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**The Role of Schematics in Electronic Circuits**

There are three main ways in which you are likely to encounter a circuit design in the ECE110 lab. Since this lab is hands-on, you will build prototype circuits. A **prototype** is *a preliminary version of a product that can be easily tested and modified before a final design is mass produced*. In the ECE110 laboratory, we construct prototype circuits on a **breadboard** (also known as a protoboard, *a construction base for connecting circuit elements without the use of solder*). To build a prototype, you would require a written guide. The easiest written guide for a student is the physical diagram.

A **physical diagram** might be a *photograph or detailed drawings depicting the physical structure of the components comprising a circuit*. The physical diagram is also suggestive of the physical layout of the circuit and attempts to leave little room for error for the novice experimenter. Finally, the most-concise method of providing a written guide is the circuit schematic.
A circuit schematic is an abstraction of a circuit that generalizes the specific components as symbols. The circuit schematic does typically suggest the physical locations of the components as they may fit into the final prototype. There is a one-to-one relationship between the components described in the circuit schematic, the physical diagram, and the prototype. It is important that an aspiring engineer learn to map one representation to another!

Figure 2: A physical diagram (a) and the circuit schematic (b) for the same circuit.

In lab, you will build simple circuits using the equipment at your bench. It is important that you learn to read a circuit schematic and use it to build a physical prototype of the circuit. Sometimes, this task can be more difficult than you would think, especially when there are many components, several test points to measure, and wires going everywhere in what may appear to be a jumbled mess! If you can learn to properly interpret a circuit schematic, this task will become much easier for you.

**Background and Terminology**

Within a circuit schematic, we will find junctions, nodes, and loops. We need to understand these definitions as we analyze our circuits. A junction is the connecting point of two or more “wires” in a circuit schematic and, for three or more wires, is often shown as a solid dot. A node is the equal-potential (constant-voltage) point joining two or more circuit elements. A node is a concept, not a physical point in a circuit. A node can be larger than a single junction, therefore a junction is merely a subset of a node. The “circle” in the figure below encloses a node.
Question 3: The circuit schematic in Figure 3 contains three nodes total. One has been circled. Circle the other two.

A loop is a path through a circuit that starts and ends at the same node never crossing through the same circuit element more than once. The loop in the figure below goes through two different resistors before returning to the same node.

Question 4: The circuit schematic in Figure 4 contains three possible loop choices. One has been labeled. Label the other two. HINT: Each of the three loops in this example will pass through exactly two resistors.