Electronics and Electromagnetism

Kirchhoff's Circuit Laws

Purpose

In this Lab, we will focus on practicing Kirchhoff's Circuit laws by building three circuits: a series circuit, a parallel circuit, and a series & parallel combination circuit. At the end of the lab, you are expected to prove that **Kirchhoff's Current Law (KCL)** and **Kirchhoff's Voltage Law (KVL)** holds true. By this time, you will also have gained enough experience in building circuits on a breadboard and therefore should be well equipped to build any circuit given to you.

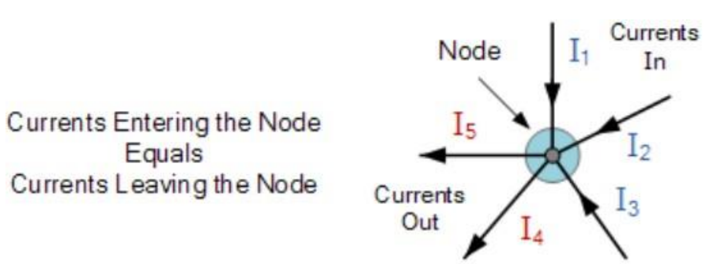
Introduction

Kirchhoff's Circuit Laws allow us to solve complex circuit problems by defining a set of basic network laws and theorems for the voltages and currents around a circuit. Sometimes in complex circuits such as bridge or T-networks, we cannot simply use Ohm's Law alone to find the voltages or currents circulating within the circuit. For these types of calculations, we need certain rules which allow us to obtain the circuit equations and for this we can use Kirchhoff's Circuit Law.

In 1845, a German physicist, Gustav Kirchhoff developed a pair or set of rules or laws which deal with the conservation of current and energy within electrical circuits. These two rules are commonly known as: Kirchhoff's Circuit Laws with one of Kirchhoff's laws dealing with the current flowing around a closed circuit, Kirchhoff's Current Law, (KCL) while the other law deals with the voltage sources present in a closed circuit, Kirchhoff's Voltage Law, (KVL).

Kirchhoff's First Law – The Current Law, (KCL)

Kirchhoff's Current Law or KCL, states that the **"total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node"**. In other words, the **algebraic sum of ALL the currents entering and leaving a node must be equal to zero**. This idea by Kirchhoff is commonly known as the **Conservation of Charge**.



$$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$$

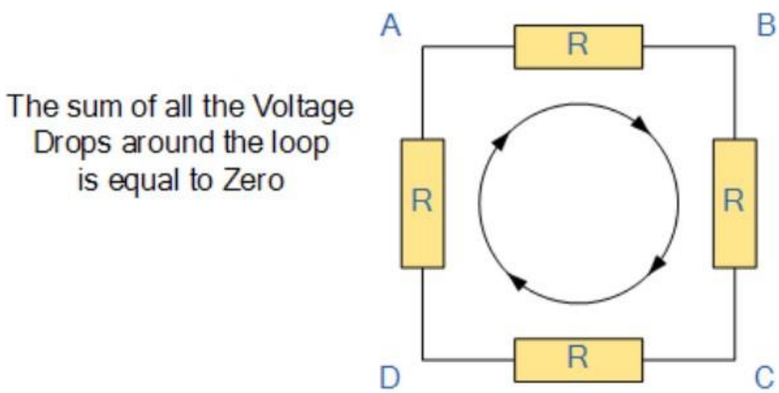
Here, the three currents entering the node, I_1, I_2, I_3 are all positive in value and the two currents leaving the node, I_4 and I_5 are negative in value. Then this means we can also rewrite the equation as.

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

The term node in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components. Also, for current to flow either in or out of a node a closed-circuit path must exist. We can use Kirchhoff's current law when analyzing parallel circuits.

Kirchhoff's Second Law – The Voltage Law, (KVL)

Kirchhoff's Voltage Law or KVL, states that **"in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop"** which is also equal to zero. In other words, the **algebraic sum of all voltages within the loop must be equal to zero**. This idea by Kirchhoff is known as the Conservation of Energy.

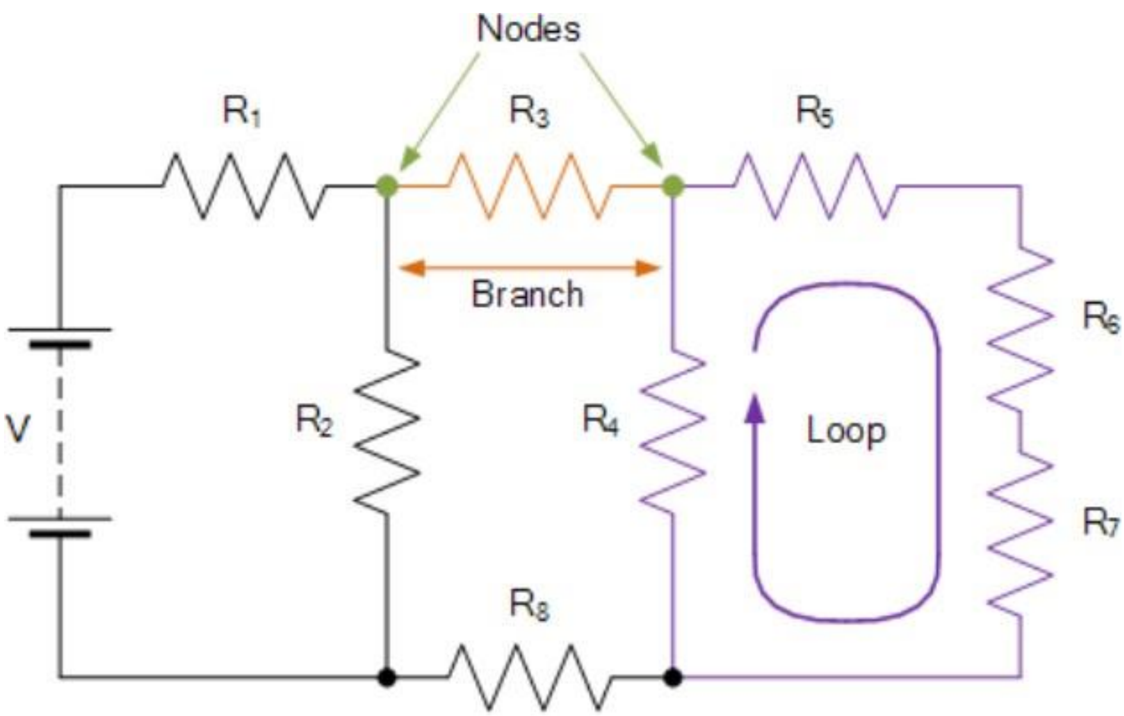


$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero. We can use Kirchhoff's voltage law when analyzing series circuits.

When analyzing either DC circuits or AC circuits using Kirchhoff's Circuit Laws several definitions and terminologies are used to describe the parts of the circuit being analyzed such as: node, paths, branches, loops, and meshes. These terms are used frequently in circuit analysis, so it is important to understand them.

Common DC Circuit Theory Terms:



Circuit – a circuit is a closed loop conducting path in which an electrical current flow.

Path – a single line of connecting elements or sources.

Node – a node is a junction, connection, or terminal within a circuit where two or morecircuit elements are connected or joined together giving a connection point between two or more branches. A node is indicated by a dot.

Branch – a branch is a single or group of components such as resistors or a source which are connected between two nodes.

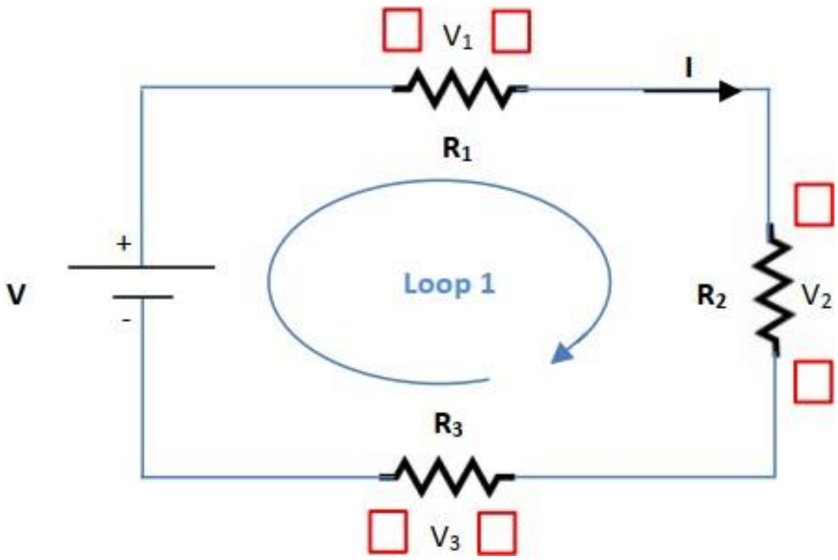
Loop – a loop is a simple closed path in a circuit in which no circuit element or node is encountered more than once.

For these tasks writing procedure isn't required but common observations are very much required, so the discussion also compulsory

Task 1 (Series Circuit)

Shown below is a circuit in which 3 resistors are connected to a DC power supply in "series" fashion. Choose R_1= 100 KΩ, R_2= 200Ω and R_3= 200 Ω. Set up your DC power supply to output 5V and build this circuit on your breadboard.

1) The chosen direction of current is clockwise (as indicated). Fill in the correct sign convention (+ or -) for the voltages in the red boxes provided (1 point)



2) Write down the KVL equation for Loop 1 in the space provided below (1 point)

   Loop1:

3) Using your DMM, measure the voltages V_1, V_2 and V_3 also current at each resistor (3 points)

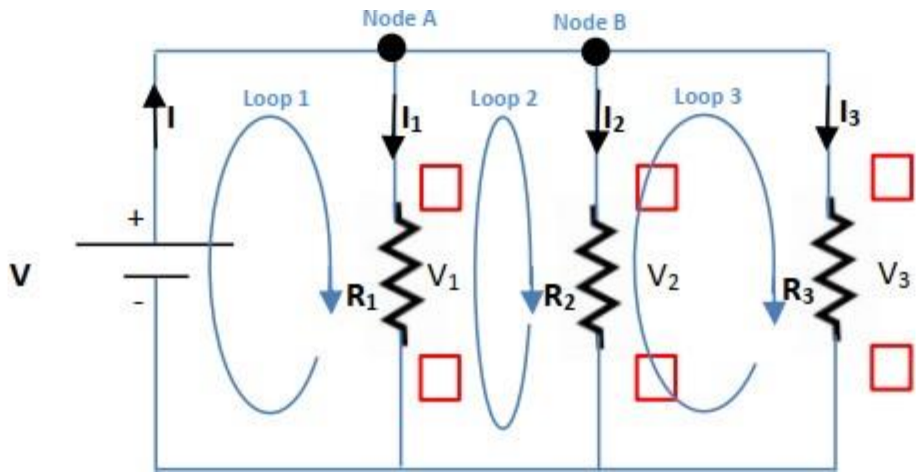
Resistor	Voltage	Current
$R_1 =$	$V_1 =$	$I_1 =$
$R_2 =$	$V_2 =$	$I_2 =$
$R_3 =$	$V_3 =$	$I_3 =$

4) Do your measured values for V_1, V_2 and V_3 agree with the KVL equation you wrote down in Q2 above? Show the proof in the space below (1 point)

Task 2 (Parallel Circuit)

Shown below is a circuit in which 3 resistors are connected to a DC power supply in "parallel" fashion. Choose R= 100Ω, R_2= 200 Ω and R_3= 200 Ω. Set up your DC power supply to output 5V and build this circuit on your breadboard.

1) Fill in the correct sign convention (+ or -) in the red boxes provided (1 point)



2) Write down the KVL equation for Loop 1, 2 and 3 in the space below (1.5 points)

   Loop1:

   Loop2:

   Loop3:

3) If I_1, I_2 and I_3 are the respective currents flowing through resistors R_1, R_2 and R_3 and if I is the current coming out of the battery, then:

   (a) Write down the KCL for Nodes A and B in the space provided below (1 points)

      Node A:

      Node B:

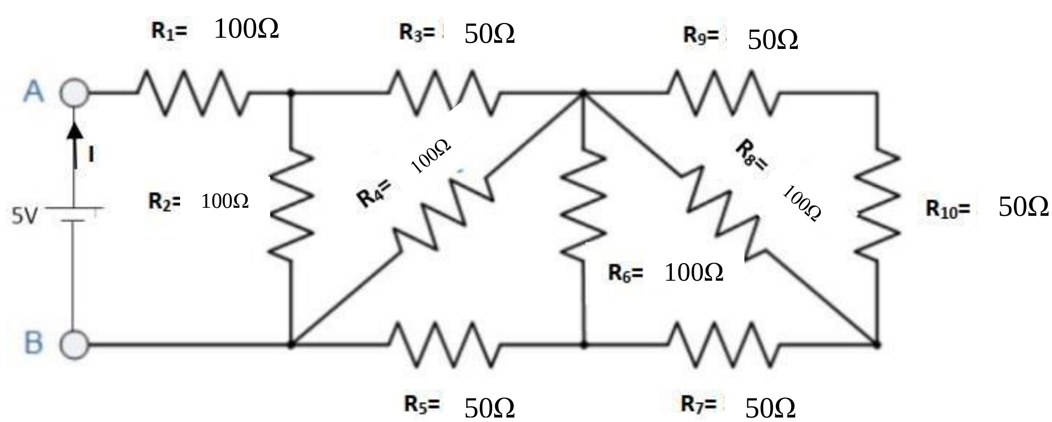
(b) Fill out the table below by measuring using DMM. Note: You must connect the DMM in series with each resistor to get the respective currents. (3 points)

Resistor	Voltage	Current
$R_1 =$	$V_1 =$	$I_1 =$
$R_2 =$	$V_2 =$	$I_2 =$
$R_3 =$	$V_3 =$	$I_3 =$

4) Do your recorded I_1, I_2 and I_3 values satisfy the KCL equations you wrote down in Q3 (a)? Show the proof in the space below (1 point).

Task 3 (Series and Parallel Combination Circuit)

1) Build the circuit shown below on your breadboard. Using your DMM, measure the voltage drop across each resistor and input the values in the table provided (5 points).
2) Using a DMM, measure current I flow out of the power supply. If you have connected the circuit correctly, then you will get the correct answer (1.5 points).



*If you are unable to find the exact resistors in the lab, try to find proportional resistors. As an example: proportion is 1:2

Resistance	Voltage
$R_1 =$	$V_1 =$
$R_2 =$	$V_2 =$
$R_3 =$	$V_3 =$
$R_4 =$	$V_4 =$
$R_5 =$	$V_5 =$
$R_6 =$	$V_6 =$
$R_7 =$	$V_7 =$
$R_8 =$	$V_8 =$
$R_9 =$	$V_9 =$
$R_{10} =$	$V_{10} =$

Current $I =$ _______________ A/ mA

3) **(Bonus!)** Without using the values of V or I, find the Equivalent resistance (**Req**) of the above circuit. Show all steps below (2 points)