Verification of Kirchhoff's Current and Voltage Laws CS1025

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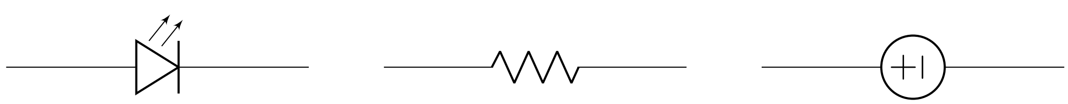
Introduction

The first part of the experiment is to set up a basic circuit consisting of a d.c voltage source, a light emitting diode (LED) and a resistor of $220\,\Omega$ connected in series with the LED. The second circuit is set up similarly to the first but with an addition of resistors of different resistance connected in parallel with the LED, having the resistor of $220\,\Omega$ connected in parallel with the combination of the LED and other resistor.

However, first of all, it it critical to understand how to read a schematic diagram, the main components of the circuit are as follows:



LED Resistor D.C Voltage Source

The second part of the experiment is to verify Kirchhoff's Current and Voltage Laws for each circuit and calculate the static resistance of the LED for each subsequent case.

Kirchoff's Current Law states that the algebraic sum of electrical currents at any node in an electrical circuit is equal to zero at every instant in time. Which in other words simply means that the total current entering a node must equal the total current leaving the node. Current entering the node is given a positive sign and that leaving is given a negative sign such that the algebraic sum at any node equals zero

Similarly, Kirchhoff's Voltage Law states that the algebraic sum of branch voltages around any loop in an electrical circuit is equal to zero at every instant in time. Summing it up to mean that the total voltage entering a node must equal the total current leaving the node. Voltage entering the node is given a positive sign and that leaving is given a negative sign such that the algebraic sum at any node equals zero

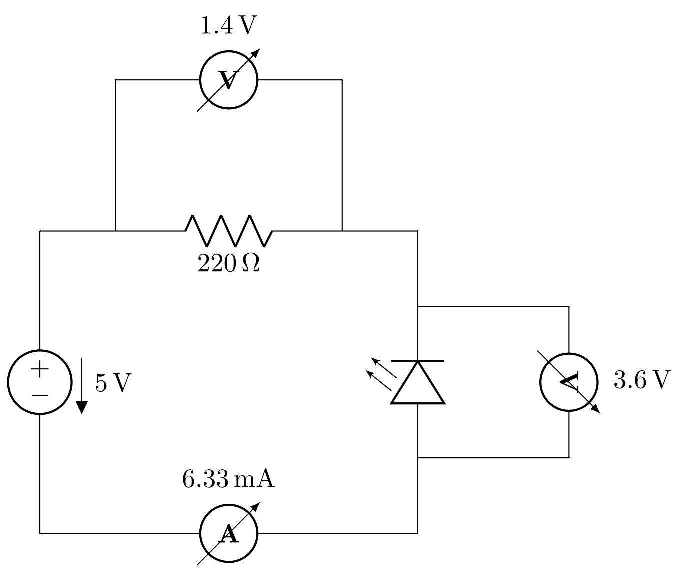
The static resistance of a diode, the LED in this case, is defined as the ratio of d.c voltage applied across the diode to the direct current flowing through it. Which is calculated according the formula below:

$$R_s = \frac{d.c\ voltage}{d.c\ current}$$

Data and Experiment Analysis

In the following experiments, voltage and current values are obtained from a digital multimeter set to measure voltage in VoltsV or current in mA. The use of the words 'voltmeter' and 'ammeter' are for explanatory reasons.

First Circuit:



The below table shows the configured measurements taken from the circuit. The resistance value of the resistor was obtained directly from the displayed

Total Input Voltage (V_t)	5 V
Total Current flow (I_t)	6.33 mA
Resistance of resistor (R_1)	220 Ω
Current through resistor (I_1)	6.33 mA
Current through LED (I_s)	6.33 mA
Voltage across resistor (V_1)	1.4 V
Voltage across LED (V_s)	3.6 V

value of the resistor; as the components are in series, the total input voltage is split between the two components, voltage readings of the resistor and the LED was obtained by placing a voltmeter in parallel with the component and reading the subsequent values off the meter; due to the components having an equal current flow as they are in series, the current reading is obtained by placing an ammeter in series with the components and taking the value from the meter.

Therefore to verify Kirchhoff's Current Law:

$$I_{in} + I_{out} = 0$$

taking the node to between the ammeter and the voltage source to prove this:

$$I_t + I_1 = 0$$

should be true.

Hence,

$$6.33 + (-6.33) = 0$$

proves that this is true.

Realising that the circuit is a series circuit, the above would be true for any point in the circuit taken to be the node.

To verify Kirchhoff's Voltage Law:

$$V_{in} + V_{out} = 0$$

as the circuit is a series circuit, the below equation:

$$V_t + (-V_1) + (-V_s) = 0$$

should be true.

Hence,

$$5 + (-1.4) + (-3.6) = 0$$

proves that this is true. Therefore proving Kirchhoff's Voltage Law.

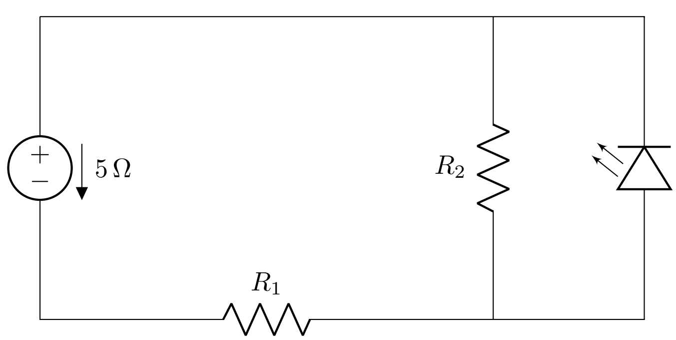
Static Resistance of LED:

$$R_s = \frac{d.c\ \ voltage}{d.c\ \ current}$$

$$R_s = \frac{3.6}{6.33 \times 10^{-3}}$$

$$R_s \approx 568.7204\,\Omega$$

Second Circuit:



The below table shows the configured measurements taken from the circuit. The resistance values of the resistors was obtained from the display value of

	Case 1	Case 2	Case 3
Total Input Voltage (V_t)	7 V	7 V	7 V
Total Current flow (I_t)	26 mA	22.5 mA	17.95 mA
Resistance of R1 (R_1)	220 Ω	220 Ω	220 Ω
Resistance of R2 (R_2)	50 Ω	100 Ω	220 Ω
Voltage across LED (V_s)	1.31 V	2.11 V	3.03 V
Voltage across R1 (V_1)	5.68 V	4.88 V	3.96 V
Voltage across R2 (V_2)	1.31 V	2.11 V	3.03 V
Current through LED (I_s)	0 mA	1.05 mA	4.27 mA
Current through R1 (I_1)	26 mA	22.5 mA	17.95 mA
Current through R2 (I_2)	26 mA	21.3 mA	13.73 mA
LED light	OFF	ON	ON

the resistors. Due to the resistor R_2 and the LED being in parallel, they have the same voltage value but share the total current, the voltage reading is obtained by placing a voltmeter in parallel with the components and reading it off the meter, the readings of voltage of resistor R_1 is taken the same way; for the current value, for each individual component, place the ammeter in series and read the meter. The current value for R_1 is obtained by placing an ammeter in series with R_1 and taking it from the meter.

Therefore to verify Kirchhoff's Current Law and Voltage Law:

$$I_{in} + I_{out} = 0$$
$$V_{in} + V_{out} = 0$$

which in this circuit means that:

$$I_1 + (-I_2) + (-I_s) = 0$$
$$V_t + (-V_1) + (-V_2) = 0$$
$$V_t + (-V_1) + (-V_s) = 0$$

where $V_2 = V_s$

Therefore, for proving Kirchhoff's Current Law:

Case 1:

$$26 + (-26) + (-0) = 0$$

Case 2:

$$22.5 + (-21.3) + (-1.05) = 1.05\,\mathrm{mA} \approx 0$$

Case 3:

$$17.95 + (-13.73) + (-4.27) = -0.05\,\mathrm{mA} \approx 0$$

Therefore to verify Kirchhoff's Voltage Law:

Case 1:

$$7 + (-5.68) + (-1.31) = 0.01\,\mathrm{V} \approx 0$$

Case 2:

$$7 + (-4.88) + (-2.11) = 0.01\,\mathrm{V} \approx 0$$

Case 3:

$$7 + (-3.96) + (-3.03) = 0.01\,\mathrm{V} \approx 0$$

It is noticed that the values differ by a negligible amount, as the experiment involves people, it may be due to human errors while measuring the readings, or errors with the measuring equipment. Despite the above, the calculations still do verify Kirchhoff's Current Law and Voltage Law.

Static Resistance of LED:

$$R_s = \frac{d.c\ voltage}{d.c\ current}$$

Case 1:

$$R_s = \frac{1.31}{0}$$
$$R_s = 0$$

Case 2:

$$R_s = \frac{2.11}{1.05 \times 10^{-3}}$$

$$R_s \approx 2009.5238\,\Omega$$

Case 3:

$$R_s = \frac{3.03}{4.27 \times 10^{-3}}$$

$$R_s \approx 709.6019\,\Omega$$

Also to note that the reason for the LED light to be off in Case 1 is that there is no current flowing through the component verified mathematically as division into 0 is not defined. All of the current flows through resistor R_1 as there is less resistance.

Conclusion

The above illustrates the verification of Kirchhoff's Current Law and Voltage Law in both series circuits and parallel circuits with mathematical proof to aid the process. Calculations for the values of the static resistance of the LED aids the understanding of the behavior of the circuit and the LED light.