Practical Works in Fundamental Electronics

Superposition Theorem

1. **Objective of the Experiment**

This experiment aims to analyze circuits with multiple voltage or current sources by isolating the effect of each source individually. This approach simplifies the problem-solving process and offers a clearer understanding of how each source impacts the overall behavior of the circuit.

2. Theoretical Background

2.1. Superposition Theorem

The superposition theorem offers a systematic approach for analyzing complex circuits by considering the effect of one energy source at a time while temporarily deactivating the others. The individual contributions from each source are then combined to determine the total voltage or current.

- **Statement 1:** The total voltage between two points in a circuit with multiple sources is the algebraic sum of the voltages produced by each source acting independently.

- **Statement 2:** The total current in a branch containing multiple energy sources is the algebraic sum of the currents generated by each source acting alone.

2.1.1. Principle of Superposition

According to the principle of superposition, the total current (I) in a branch or voltage (U) across two points is the algebraic sum of the contributions from each source, assuming that only one source is active at a time. To implement this theorem:

1. Deactivate all sources except one, replacing voltage sources with short circuits and current sources with open circuits.

2. Calculate the resulting current or voltage for the active source.

3. Repeat this process for each source, then sum the individual contributions to obtain the total current or voltage.

For a circuit with (N) generators:

- **State 1**: All sources are deactivated except generator 1 → Compute (I_1).

- **State 2:** All sources are deactivated except generator 2 → Compute (I_2).

- **State N**: All sources are deactivated except generator (N) → Compute (I_N).

The overall **voltage** between two points is:

$U=U_1+U_2+\cdots+U_N$

Similarly, the total **current** in a branch is:

$I=I_1+I_2+\cdots+I_N$

This method ensures accurate analysis by accounting for the effect of each source individually, making it particularly effective for circuits with complex configurations.

Note:

Deactivating a generator refers to the process of treating it as non-operational:

- For a voltage source: This involves setting the voltage across its terminals to zero, which effectively means replacing the ideal voltage source with a short circuit.

- For a current source: This entails considering the output current to be zero, accomplished by replacing the current source with an open circuit.

These procedures are essential for accurately applying the superposition theorem, enabling a detailed analysis of each generator's contribution to the overall behavior of the circuit.

Example:

Consider the circuit illustrated below:

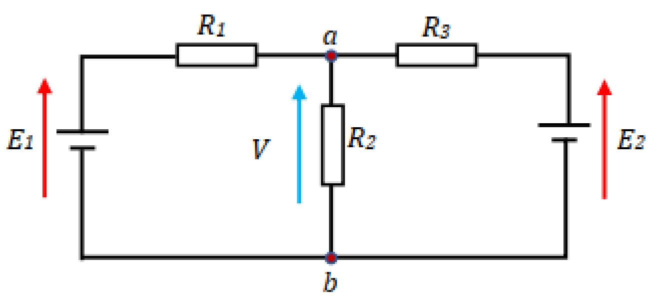

Figure.1

In this example, we will apply the superposition theorem to analyze the contributions of each generator independently.

According to the superposition theorem, the voltage V between points a and b is:

$$\mathbf{V=V_1+V_2}$$

Where:

- V1 is the voltage between points a and b when E1 acts alone (with E2 neutralized).

- V2 is the voltage between points a and b when E2 acts alone (with E1 neutralized).

a. Calculate V1

By neutralizing E2, the circuit in Figure 1 will appear as follows:

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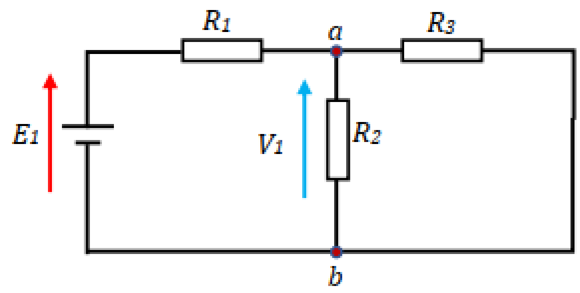


Figure.2

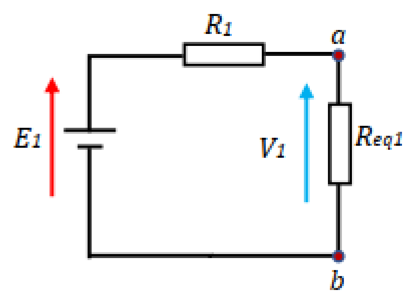
In this configuration, you can now calculate the voltage **V1** across points points a and b based on the remaining components in the circuit.

To calculate the voltage **V1**, we must first determine the equivalent resistance between the two points a and b (the equivalent resistance of the two resistors R2 and R3 which are in parallel):

$$\frac{1}{Req1} = \frac{1}{R2} + \frac{1}{R3}$$

Once $Req1$ is calculated, you can proceed to determine V1 using the appropriate voltage division or Ohm's Law techniques.

Thus, the circuit can be simplified to the following:

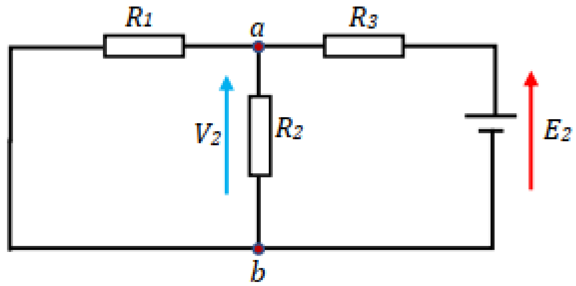


By using the concept of a voltage divider, we find that:

$$V1 = E1\frac{Req1}{Req1 + R1}$$

b. Calculate V2

By neutralizing E1, the circuit in Figure 1 will appear as follows:

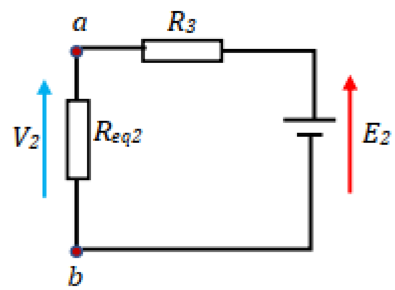


To calculate the voltage **V2**, we must first determine the equivalent resistance between the two points a and b (the equivalent resistance of the two resistors R1 and R2 which are in parallel):

$$\frac{1}{Req2} = \frac{1}{R1} + \frac{1}{R2}$$

Once $Req2$ is calculated, you can proceed to determine V2 using the appropriate voltage division or Ohm's Law techniques.

Thus, the circuit can be simplified to the following:



By using the concept of a voltage divider, we find that:

$$V2 = E2\frac{Req2}{Req2 + R3}$$

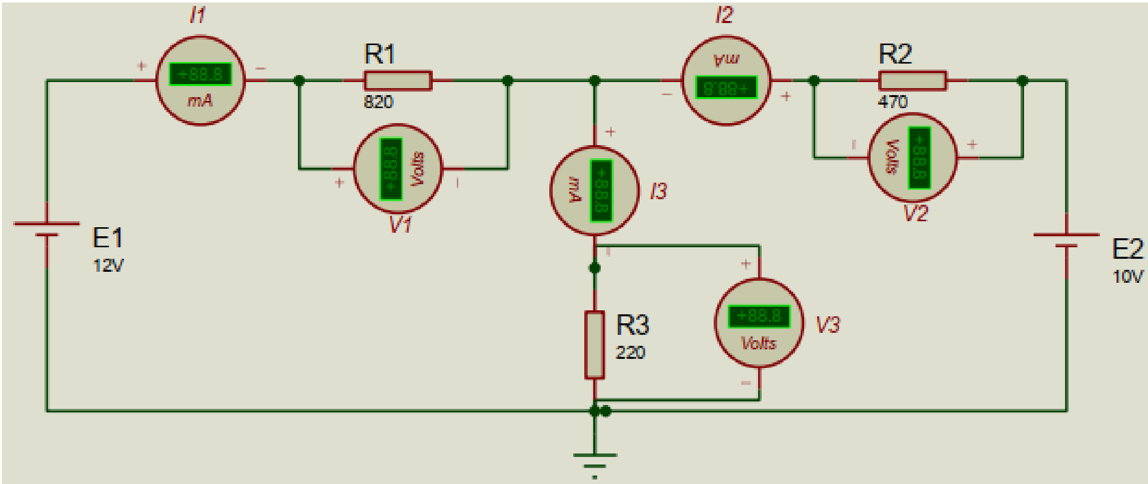
Finally, the voltage **V** between the two points a and b is equal to the algebraic sum of the two voltages **V1** and **V2:**

$$V = V1 + V2 = E1\frac{Req1}{Req1 + R1} + E2\frac{Req2}{Req2 + R3}$$

3. Experiment Procedure

3.1. Individual Work

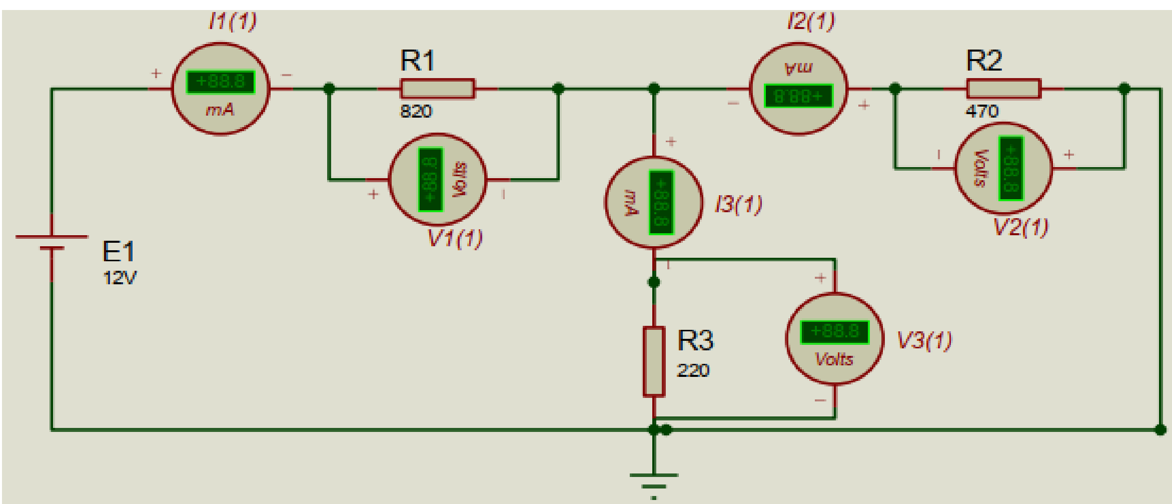
a. Using Proteus (see Appendix E), construct the circuit shown below:



b. Conduct the circuit simulation and complete the table below:

V1 (V)	V2 (V)	V3 (V)	I1(mA)	I2 (mA)	I3 (mA)

c. Short-circuit the voltage source E2 to obtain the following circuit:



d. Simulate this circuit and complete the table below:

***V1(1)* (V)**	***V2* (1) (V)**	***V3* (1) (V)**	***I1* (1)(mA)**	***I2* (1) (mA)**	***I3*(1) (mA)**

e. Short-circuit the voltage source E1 to obtain the circuit shown below:

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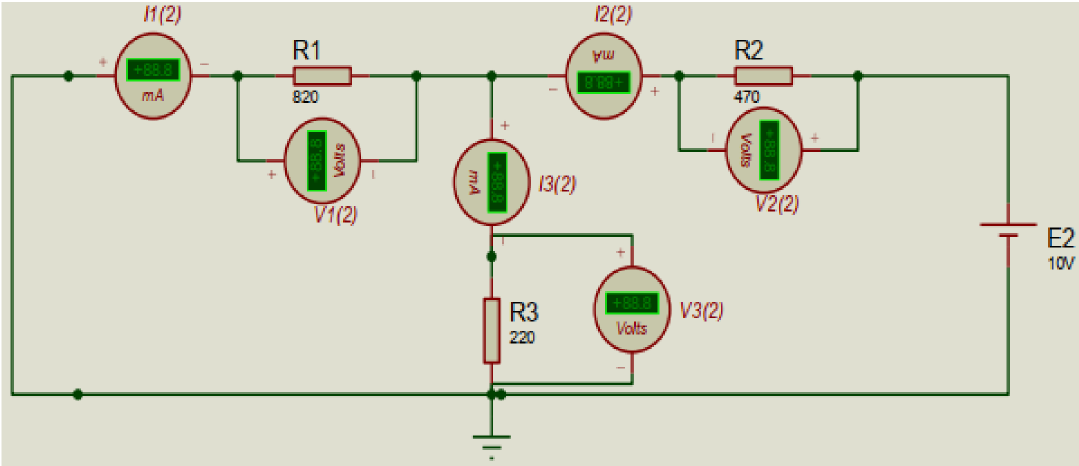


f. Simulate this circuit and complete the table below:

V1(2) (V)	V2 (2) (V)	V3 (2) (V)	I1 (2)(mA)	I2 (2) (mA)	I3(2) (mA)

g. Verify that:

$$Vn = Vn(1) + Vn(2) \qquad 1 \leq n \leq 3$$

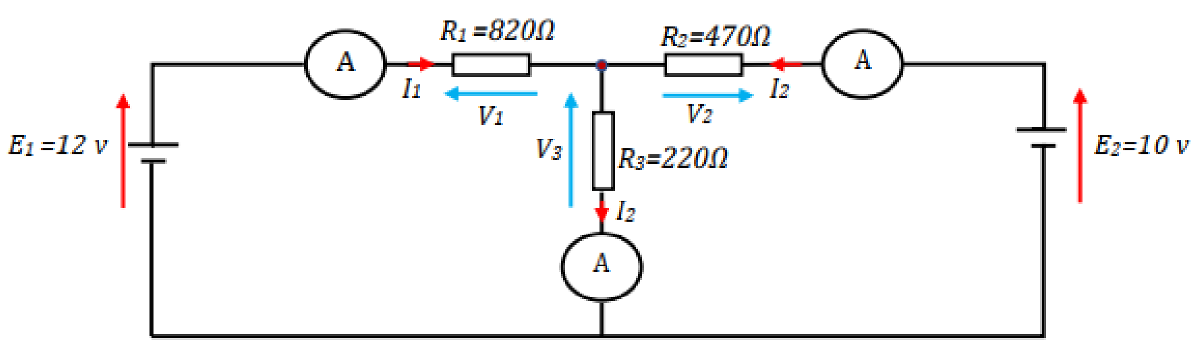
And

$$In = In(1) + In(2) \qquad 1 \leq n \leq 3$$

3.2. In-Person Activity

3.2.1. Circuit Construction

a. Construct the circuit illustrated below:



b. Record the various current and voltage measurements in the table below:

V1	V2	V3	I1	I2

c. We will now attempt to measure the currents and voltages in the previous circuit using the superposition theorem.

1.**Step 1**: E1 Alone, E2 Deactivated:

- Draw and assemble the circuit.
- Record the various current and voltage measurements in the table below:

V'1	V'2	V'3	I'1	I'2	I'3

2. Step 2: E2 Alone, E1 Deactivated:

- Draw and assemble the circuit.
- Record the various current and voltage measurements in the table below:

V''1	V''2	V''3	I''1	I''2	I''3

3.2.2. Tasks to Complete

a. What equipment is required to set up these circuits?

b. Theoretically, calculate the voltages across the resistors R1, R2, and R3 using the superposition theorem.

c. Theoretically ,calculate the current intensities in all branches using the superposition theorem.

d. Based on the voltage values obtained earlier (both measured practically and calculated theoretically), can we confirm that the superposition theorem holds for these voltages? Why or why not?

e. Based on the current values obtained earlier (both measured practically and calculated theoretically), can we confirm that the superposition theorem holds for these currents? Why or why not?

f. The power dissipated in a resistor is given by the relationship:

$P = I^2 * R = I * V$, Verify whether the superposition theorem is applicable for calculating the power dissipated by a resistor (R1, R2, and R3). In other words, does the relationship P = P' + P" hold true?