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Experiment No. 3

Verification of Superposition Principle

Objective

This experiment aims to experimentally verify the Superposition theorem, which is an analytical technique for determining currents/voltages in a circuit with more than one emf source.

Theory

The Superposition Principle is a fundamental concept in electrical circuits that states that in any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately, and all other sources are replaced by their internal resistance. The superposition theorem is used to solve networks where two or more sources are present and connected. The current or voltage through any component in a circuit is the sum of the effects of each individual source acting alone. In other words, the principle states that **the total response of a circuit with multiple sources is the sum of the responses of the circuit to each individual source acting alone.** This principle is widely used in circuit analysis to simplify complex circuits and solve them with ease.

In a **linear circuit** containing multiple independent sources and linear elements (e.g., resistors, inductors, and capacitors), the voltage across (or the current through) any element when all the sources are acting simultaneously may be obtained by adding algebraically all the individual voltages (or currents) caused by each independent source acting alone, with all other sources deactivated.

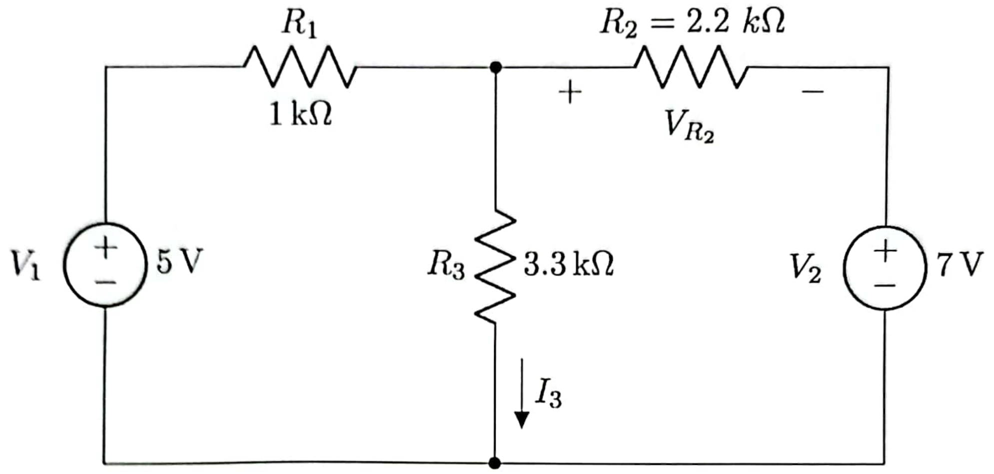
An independent **voltage source** is deactivated (made zero) by **shorting** it, and an independent **current source** is deactivated (made zero) by **open-circuiting** it. However, if a dependent source is present, it must remain active during the superposition process.

Apparatus

- Multimeter
- Resistors ($1\ k\Omega,\ 2.2\ k\Omega,\ 3.3\ k\Omega$).
- DC power supply
- Breadboard
- Jumper wires

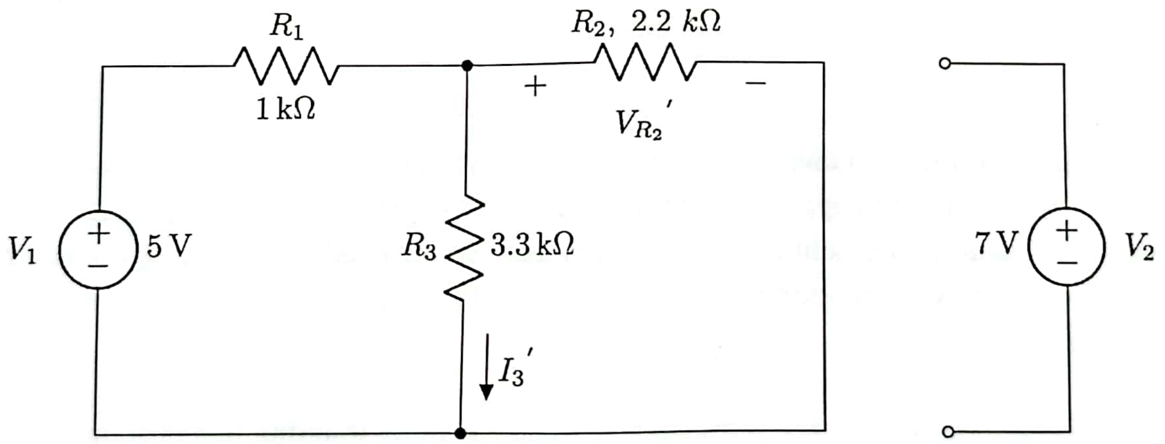
Procedures

- Measure the resistances of the provided resistors and fill up the data table (Table 1).
- Construct the following circuit on a breadboard. Try to use minimum number of jumper wires:



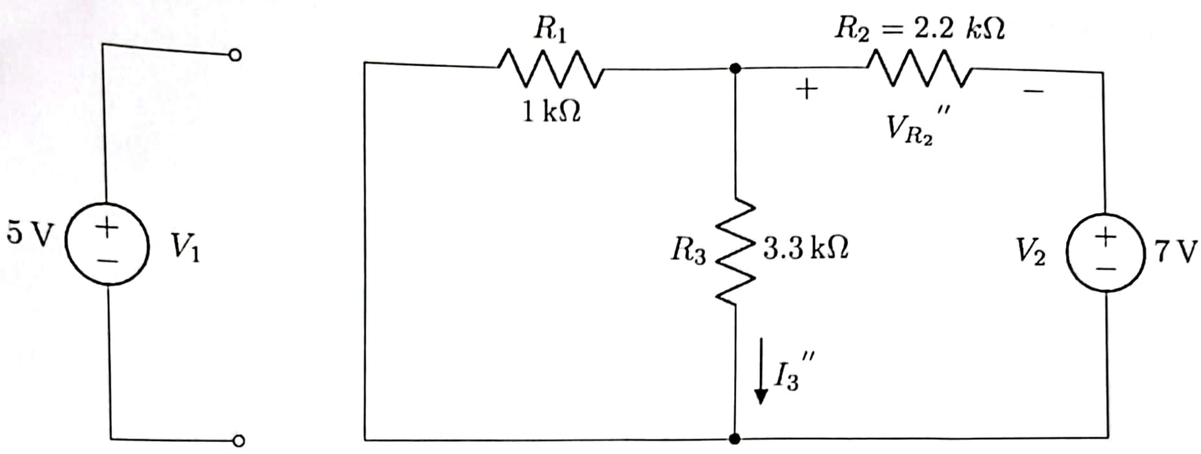
Circuit 1

- Measure the voltage across the resistors R_2, R_3 and current through the resistor R_3. Use a Multimeter to measure the voltage and use Ohm's law to calculate the current (I_3) through R_3. Fill up the data tables.
- Render V_1 inactive (keeping V_2 active) and construct the following circuit.



Circuit 2

- Measure the voltage across the resistors R_2, R_3 and current through the resistor R_3. Use a Multimeter to measure the voltage and use Ohm's law to calculate the current (I_3') through R_3. Fill up the data tables.
- Render V_2 inactive (keeping V_1 active) and construct the following circuit.



Circuit 3

- Measure the voltage across the resistors R_2, R_3 and current through the resistor R_3. Use a Multimeter to measure the voltage and use Ohm's law to calculate the current (I_3'') through R_3. Fill up the data tables.
- Verify if $I_3 = I_3' + I_3''$. This validates the superposition theorem for the current through R_3.
- Verify if $V_{R_2} = V_{R_2}' + V_{R_2}''$. This validates the superposition theorem for the voltage across R_2.

Data Tables

Signature of Lab Faculty:		Date:	24.02.25

** *For all the data tables, take data up to three decimal places, round to two, then enter into the table.*

Table 0: Resistance Data

For all your future calculations, please use the observed values only **(even for theoretical calculations)**.

Notation	Expected Resistance	Observed Resistance (kΩ)
R_1	1 kΩ	0.981
R_2	2.2 kΩ	2.178
R_3	3.3 kΩ	3.231

Table 1: Current through R_3 and voltage across R_2

In the following table, I_3 is the current through R_3 and V_{R_2} is the voltage drop across the resistor R_2. A similar syntax applies to the remaining resistors. Also, calculate the percentage of error between expected and observed values of $I_3' + I_3''$.

Observation	I_3 with both V_1 and V_2 active (mA)	I_3' with only V_1 is active (mA)	I_3'' with only V_2 is active (mA)	$I_3' + I_3''$ (mA)
Experimental	1.445	0.886	0.56	1.446
Theoretical	1.438	0.882	0.556	1.438
Observation	V_{R_2} with both V_1 and V_2 active (V)	V_{R_2}' with only V_1 is active (V)	V_{R_2}'' with only V_2 is active (V)	$V_{R_2}' + V_{R_2}''$ (V)
Experimental	−2.371	2.861	−5.23	−2.369
Theoretical	−2.35	2.85	−5.20	−2.35

- **Percentage of error** $= \left| \dfrac{Observed\ Value - Expected\ Value}{Expected\ Value} \right| \times 100\%$

N.B: Here, the Expected values are I_3, V_{R_2} and the Observed values are $I_3' + I_3''$ and $V_{R_2}' + V_{R_2}''$ respectively.

Hence, Percentage of error in $I_3' + I_3''$ calculation = $\boxed{0.069\ \%}$

Hence, Percentage of error in $V_{R_2}' + V_{R_2}''$ calculation = $\boxed{0.084\ \%}$

1. Refer to the Data Table 2 to answer the following questions–

(a) Calculate the **power associated** with R_2 using the experimentally measured values of currents or voltages in Table 2 when:

- Only V_1 source is active.
- Only V_2 source is active.
- Both V_1 and V_2 sources are active.

Fill out the Table given below and verify, whether the superposition theorem is verified or not in this case. **You don't need to take any new readings for this task.** Use previous data from Table 2 to calculate the power. Remember, power consumed by a resistor can be written as, $P = VI = I^2R = \frac{V^2}{R}$

Observation	P_{R_2} when both V_1 and V_2 active $P_{R_2} = \frac{V_{R_2}^2}{R_2}$ (W)	P'_{R_2} when only V_1 is active $P'_{R_2} = \frac{V'^2_{R_2}}{R_2}$ (W)	P''_{R_2} when only V_2 is active $P''_{R_2} = \frac{V''^2_{R_2}}{R_2}$ (W)	$P'_{R_2}+P''_{R_2}$ (W)
Experimental	2.57	3.76	12.56	16.32
Theoretical	2.54	3.73	12.42	16.15

(b) Is the Superposition Principle applicable in the case of Power?

☐ Yes ☑ No

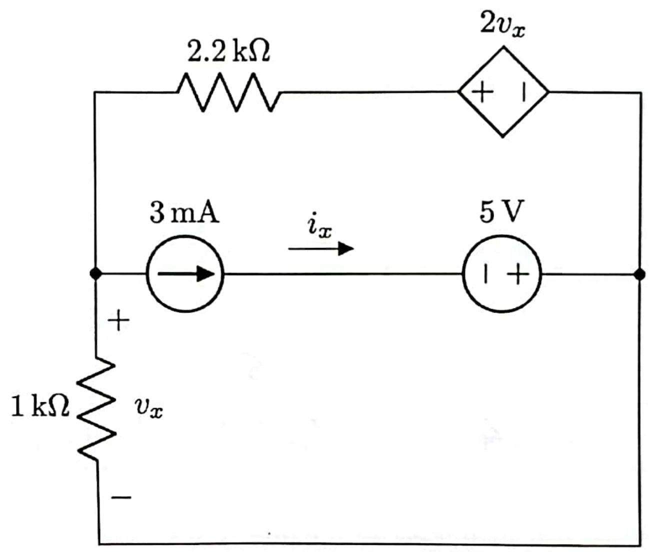
(c) How would you relate your findings from this to the concept of linearity? Why does/doesn't it work when it comes to Power?

The superposition principle is not applicable for power because power is a non-linear quantity. $P = VI$ and $P = I^2R$ where voltage and current multiply and square linearity shows that outputs are directly proportional to inputs. In case of power, input and output is not connected to linearity. In additional linear system we can write $P = I_1^2R + I_2^2R$.

2. Why was a short circuit wire required to be connected between the corresponding terminals while turning off a voltage source? Why wasn't simply turning off the power switch enough to deactivate the source?

A short circuit wire is used to dettach any left over charges or potential difference which prevents any risk of shortcut. This wire ensures deactivation completely. It prevents or stop extra ~~so~~ current or voltage that can affect the circuit analysis.

3. For the circuit shown below,



(a) Show mathematically using the Superposition Principle that the 5 V voltage source in series with the current source has no contribution to the current i_x. *[Hint: dependent or controlled sources cannot be deactivated]*.

From Superposition principle we see that independent voltage source is deactivated with a short-circuit and current source with an open-circuit.

Analysis:

1) $i_x = 3mA$, $V_x = i_x \cdot 1k\Omega = 3V$

So, 5V source doesn't affect current by 3mA source as it is in series connection.

ii) In case of 5V source at first we deactivate 3mA current source by open circuit. The $2V_x$ depends on V_x which we get from current I of 1kΩ.
So, the contribution of 5V source to i_x is none and total i_x is 3mA because of the current source.

(b) Why the 5 V voltage source couldn't give rise to a current? Can you draw any conclusions about the resistances of an ideal voltage and current source from this?

The 5V voltage source couldn't give rise to current because it is in series with an proper current source. This type of ideal current source ensures fixed current flow and ideal voltage source maintains a fixed voltage. So, ideal sources ensures constant voltage or fixed current and their circuit condition doesn't affect that.

Report

1. Fill up the theoretical parts of all the data tables.
2. Answers to the questions.
3. Discussion *[your overall experience, accuracy of the measured data, difficulties experienced, and your thoughts on those]*. Add pages if necessary.

From superposition priciple, we made the circuit on breadboard using 2DC circuit power supply and 3 resistors. We have used multimeter for measuring voltage and resistance. Also, we used jumper wires to measure the voltage across R_2 and R_3 and I_3 current which is through R_3

resistor (3.3kΩ). We also have used ohm's law to find I_3 through R_3 (3.231kΩ) and we did this process for 5V voltage source and 7V acti voltage source by keeping them active individually for two different times when other one was inactive to find current I_3 and voltage for R_2, R_3. We ~~also~~ ~~calculated~~ observed current $I_3 = 1.445$ mA where I_3' with V_1 active is 0.886mA and I_3'' with V_2 active is 0.56 mA ~~which~~ and I_3 is equal to $I_3' + I_3''$. It satisfies the superposition theorem. Again, we found $V_{R_2} = V_{R_2}' + V_{R_2}''$ for resistor R_2. After collecting all these values and data, we calculated error percentage which is ~~%~~

$I_3' + I_3'' = 0.069\%$ and $V_{R_2}' + V_{R_2}'' = 0.084\%$.