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Experiment No. 1

Introduction to Series and Parallel Circuit Connections

Objective

The aim of this experiment is to acquaint students with series and parallel circuit connections and to properly identify them on a breadboard or from a schematic diagram.

Theory

An electrical circuit is a continuous path through which electrical current flows. Amongst various circuit combinations, two prominent ones are called "Series" and "Parallel". For a connection to be called "**Series**", it must fulfil the following criteria:

- All the components must be connected *one after the other*.
- The *same current* must flow through all the components.

For instance, in the following circuit, we have N resistors: R_1, R_2, R_3, ..., R_N connected one after another and the same current I is flowing through them. All of these series resistors can be combined into just one equivalent resistance,

$$R_{eq} = R_1 + R_2 + R_3 ... + R_N = \sum_{i}^{N} R_i$$

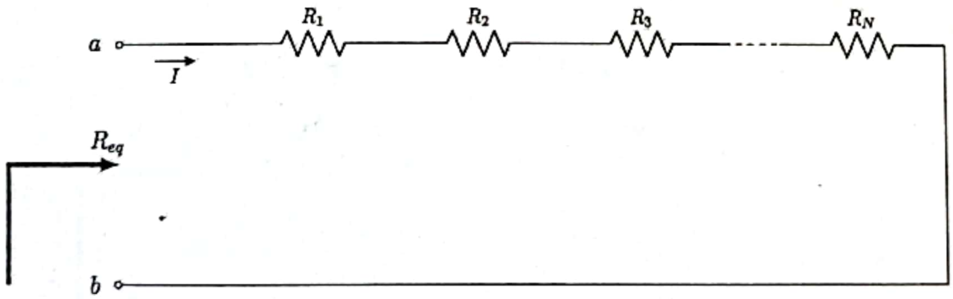


Figure: A series connection

Similarly, in a "**Parallel**" connection,

- All the components must be connected between the *same two nodes*.
- The *same potential (voltage) drop* should exist across all the components.

For example, in the following figure, we have N resistors with resistances: R_1, R_2, R_3, ..., R_N connected at the same two nodes a and b. And therefore, the voltage drop across all the resistors are, $\Delta V = V_a - V_b$. Hence, we conclude that the resistors are connected in parallel. The equivalent resistance of these resistors is R_{eq} where,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} ... + \frac{1}{R_N} = \sum_{i}^{N} \frac{1}{R_i}$$

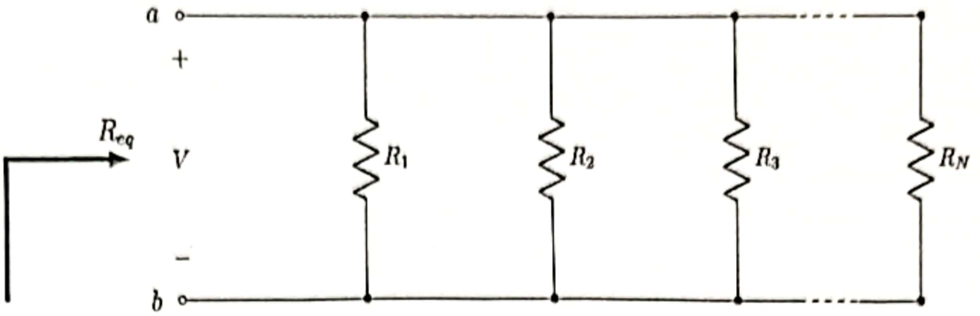


Figure: A parallel connection

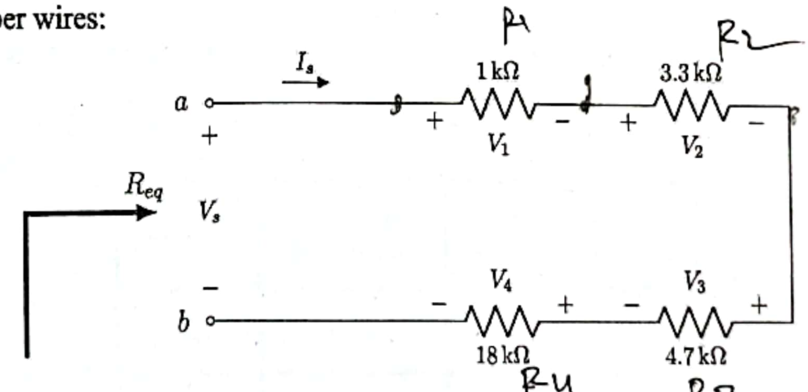
In this experiment, we will learn how to connect circuits in breadboards and how to identify series and parallel connections,

Apparatus

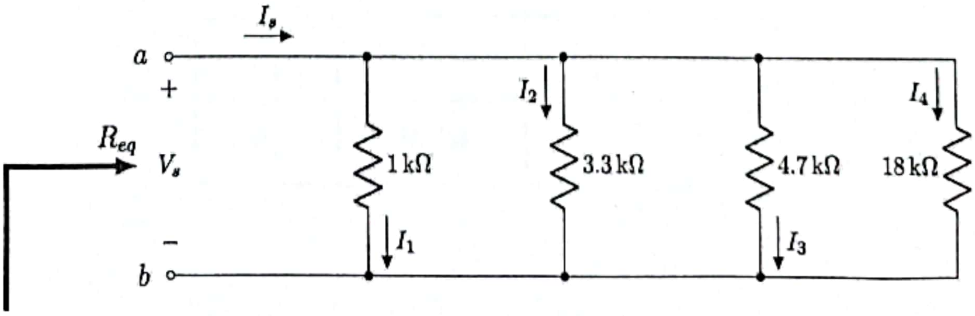
- Multimeter
- Resistors
- DC power supply
- Breadboard
- Jumper wires

Procedures

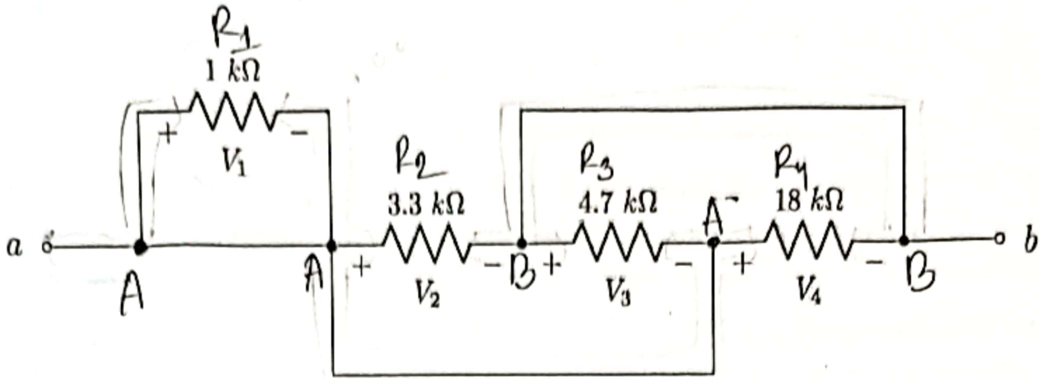
- Measure the resistances of the provided resistors and fill up the data table.
- Construct the following circuits on a breadboard. Try to use minimum number of jumper wires:



Circuit 1



Circuit 2



Circuit 3

- Measure the equivalent resistance using a multimeter. **To do this, disconnect the power supply (if any) and connect the multimeter across the open terminals.**
- Apply **6 V** potential drop across the terminals a and b. Use the DC power supply to connect the positive terminal to node a and the negative terminal to terminal b.
- Measure the voltage and current across each resistors. Use Multimeter for measuring the voltage and use Ohm's law to calculate the current through each resistor. Fill up the data tables.

Data Tables

Signature of Lab Faculty:	Afd.	Date:	27.1.23

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

Table 1: 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	1.003
R_2	3.3 kΩ	3.254
R_3	4.7 kΩ	4.63
R_4	18 kΩ	18.18

$R_1 = 1$ $R_2 = 3.3$ $R_3 = 4.7$ $R_4 = 18$

Table 2: Data from Circuit 1

$V_1 = I_s R_1$
$V_2 = I_s R_2$

In the following table, V_1 is the voltage drop across resistor R_1 and I_1 is the current through it. Similar syntax applies to remaining resistors. **For theoretical calculations, please note that, in series connection, the supplied voltage will be divided proportionally to the resistances.** The voltage supplied to the complete circuit is denoted by V_s and the current being supplied to the whole network is denoted as I_s. Also, calculate the percentage of error between experimental and theoretical values of R_{eq}.

Observation	R_{eq} (kΩ)	V_s (V) (from dc power supply)	V_s (V) (using multimeter)	$I_s = \frac{V_s}{R_{eq}}$ (mA)	V_1 (V)	$I_1 = \frac{V_1}{R_1}$ (mA)	V_2 (V)	$I_2 = \frac{V_2}{R_2}$ (mA)	V_3 (V)	$I_3 = \frac{V_3}{R_3}$ (mA)	V_4 (V)	$I_4 = \frac{V_4}{R_4}$ (mA)
Experimental	27	5	5	.185	.186	.185	.602	.185	.858	.185	3.366	0.185
Theoretical	27.067			.184	.184	.184	.607	.184	.865	.184	3.312	.184

$$\text{Percentage of error} = \left|\frac{Experimental - Theoretical}{Theoretical}\right| \times 100\%$$

Here, Percentage of error in R_{eq} calculation = 0.247 %

Table 3: Data from Circuit 2

In a parallel connection, all the voltage drops are same across the components. Hence, we only need the supply voltage V_s. **However, the current across each component is inversely proportional to the resistance values.**

Observation	R_{eq} (kΩ)	V_s (V) (from dc power supply)	V_s (V) (using multimeter)	$I_s = \frac{V_s}{R_{eq}}$ (mA)	$I_1 = \frac{V_s}{R_1}$ (mA)	$I_2 = \frac{V_s}{R_2}$ (mA)	$I_3 = \frac{V_s}{R_3}$ (mA)	$I_4 = \frac{V_s}{R_4}$ (mA)
Experimental	0.367	5	5	13.62	4.98	1.536	1.08	0.28
Theoretical	~~[illegible]~~ 0.63			7.936	5	1.515	1.063	0.277

Here, Percentage of error in R_{eq} calculation = ~~[illegible]~~ 41.7 %

$V = IR_2$

Table 4: Data from Circuit 3

Collect the following data.

Observation	R_{ab} (kΩ)	V_s (V) (from dc power supply)	V_s (V) (using multimeter)	$I_s = \frac{V_s}{R_{eq}}$ (mA)	V_1 (V)	$I_1 = \frac{V_1}{R_1}$ (mA)	V_2 (V)	$I_2 = \frac{V_2}{R_2}$ (mA)	V_3 (V)	$I_3 = \frac{V_3}{R_3}$ (mA)	V_4 (V)	$I_4 = \frac{V_4}{R_4}$ (mA)
Experimental	0.614	5	5	8.14	0	0	5	1.536	-5	-1.08	5	0.27
Theoretical	1.75			2.857	0	0	0.866	0.262	0.608	0.129	0.159	0.008

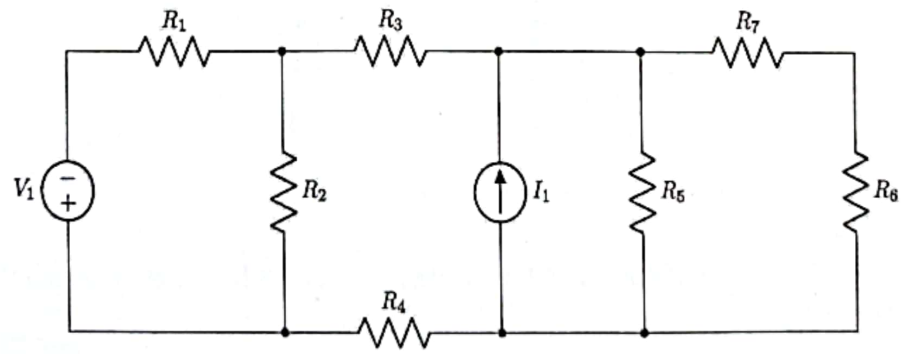
Here, Percentage of error in R_{eq} calculation = 64.91 %

How are the resistors in circuit 3 connected with each other? Justify your answer.

The first resistor in the circuit is sorted and rest are connected with each other in a parallel combination.

Questions

1.



(a) After taking voltage and currents measurements in a laboratory for the circuit shown above, the currents through the R_4 and R_7 resistors are found to be equal. Are R_4 and R_7 in series?

☐ Yes ☑ No

Justify your choice.

Current flow (i_2) through R_4 is: $i_2 = \frac{i_2 R_2 - i_2 R_5}{R_4 + R_3 - R_2}$
Current flow (i_4) through R_7 is: $i_4 = \frac{-i_1 R_5}{R_6 + R_9}$
Here we see that i_2 and i_4 have differrent equation, although they might be equal but that doesn't mean R_2 and R_7 in series combination.

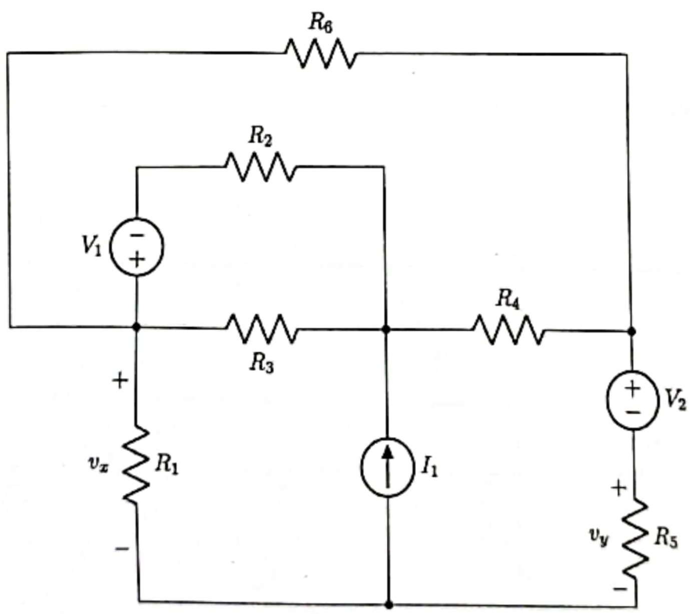
(b) R_1, R_2, and, R_3 are connected in

☐ Series ☐ Parallel ☑ None of the two ☐ Cannot be predicted

Explain your choice.

R_1, R_2, R_3 are in mixture of both series and parallel combination.

2.



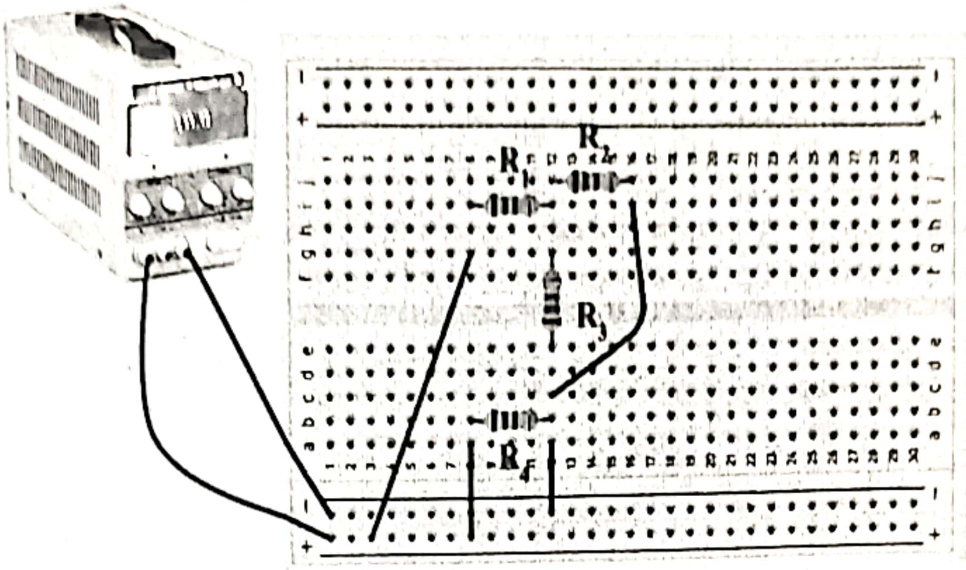
(a) If the voltages v_x and v_y are equal, are R_1 and R_5 in parallel?

☐ Yes ☑ No

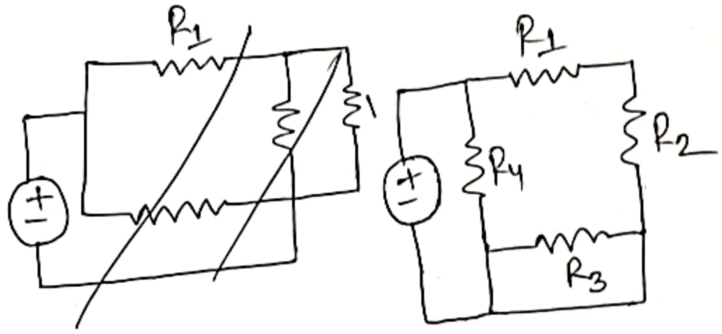
Justify your answer.

R_1 and R_5 are not between same pair of nodes, so they are not parallel.

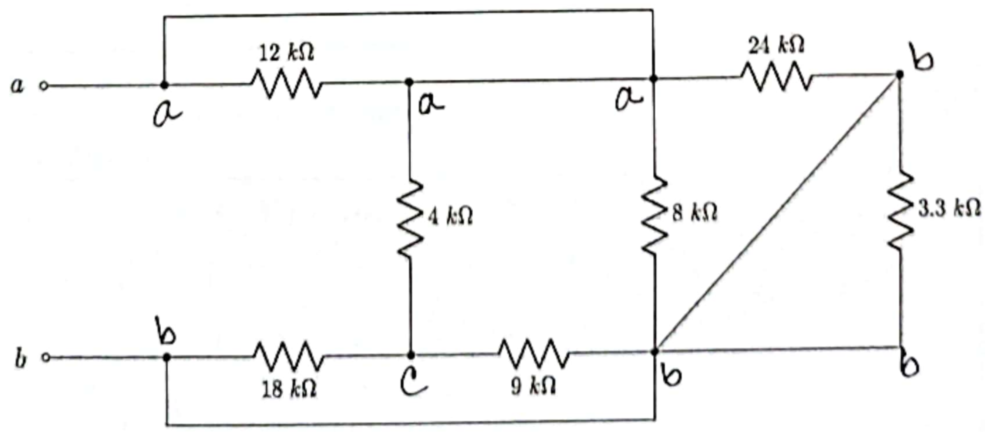
3.



Draw a circuit diagram of the circuit shown on the breadboard above.



4. For the following circuit:



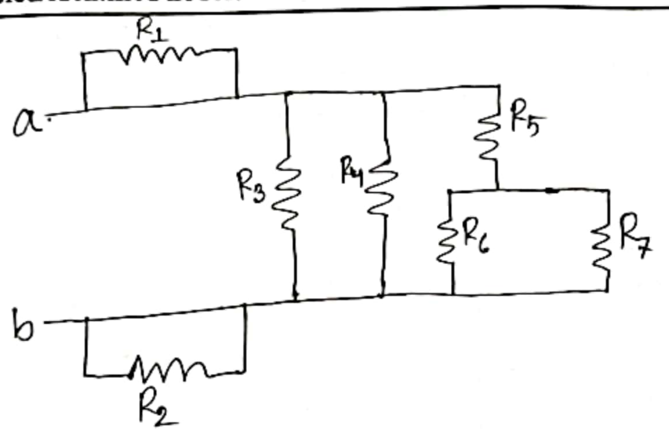
(a) How many nodes are there. Mark and label all the nodes in the circuit diagram.

There are 3 nodes.

(b) Based on the node labels in (a), fill out the following table by entering the starting and ending nodes in each row that connect the corresponding circuit element.

Circuit Element	Starting/Ending Node	Ending/Starting Node
12 kΩ Resistor	1	1
4 kΩ Resistor	1	3
18 kΩ Resistor	2	3
9 kΩ Resistor	3	2
8 kΩ Resistor	1	2
24 kΩ Resistor	1	2
3.3 kΩ Resistor	2	2

(c) Based on the table in (b), draw a simplified version of the circuit using the labeled/identified nodes.



$R_1 = 12\ \Omega$
$R_2 = 3.3\ \Omega$
$R_3 = 8\ \Omega$
$R_4 = 24\ \Omega$
$R_5 = 4\ \Omega$
$R_6 = 18\ \Omega$
$R_7 = 9\ \Omega$

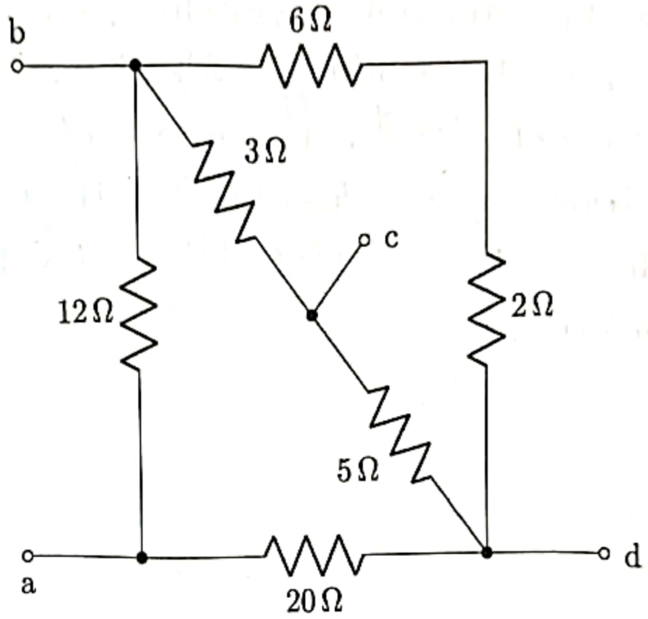
(d) Determine the equivalent resistance between terminals a and b from the reduced circuit drawn in (c).

Here, R_6 and R_7 are in parallel. $1/R_{eq_1} = \left(\frac{1}{18} + \frac{1}{9}\right)$
So $(R_{eq_1})^{-1} = (1/18 + 1/9)^{-1}$. Then $R_{eq_2} = R_{eq_1} + R_5 = 9.993\ K\Omega$.
Now, R_{eq_2}, R_3, R_4 are in parallel. So,

$$R_{eq} = \left(\frac{1}{9.993} + \frac{1}{8} + \frac{1}{24}\right)^{-1}$$
$$= 3.749\ K\Omega$$

5. For the following circuit, determine R_{ab}, R_{ad}, R_{bd} and R_{bc}. Use logical operators to indicate the series-parallel combinations. For exmple, the following equation of R_{xy} means, two 10 Ω resistors are in parallel, their combination is in series with a 5 Ω resistor, and the total is again parallel with a 20 Ω resistor.

$$R_{xy} = \{(10 \,||\, 10) + 5\} \,||\, 20$$



$R_{ab} = (6+2)\Omega = 8\Omega, (5+3)\Omega = 8\Omega$ $8 \| 8 = 4\Omega, (4+20)\Omega = 24\Omega$ $= 24 \| 12 = 8\Omega$	$R_{ad} = (3+5) = 8\Omega, 8 \| 8 = 4\Omega,$ $(6+2) = 8\Omega, (12+4) = 16\Omega$ $= 16 \| 20 = 8.889\Omega$
$R_{bd} = (6+2)\Omega = 8\Omega, (12+20) = 32\Omega$ $= 8 \| 8 \| 32 = 3.556\Omega$	$R_{bc} = (12+20) = 32\Omega, (6+2) = 8\Omega$ $32 \| 8 = 6.4\Omega, (6.4+3) = 9.4\Omega$ $= 9.4 \| 5 = 3.26$

Report

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

My overall experience the introduction to series and parallel circuit connections experiment provided a comprehensive overview of fundamental concepts in electrical circuits. The accuracy of the measured data was satisfactory. One common difficulty was related to breadboard connection, especially for those who were new to working with these tols. To further improve the experiemnt, I personally suggest offering extra guidance for troubleshooting common issues could address the difficulties faced by some group members.