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Experiment No. 1

Introduction to Series and Parallel Circuit Connections

Objective

This experiment aims 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 fulfill the following criteria:

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

For instance, we have N resistors in the following circuit: 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,

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

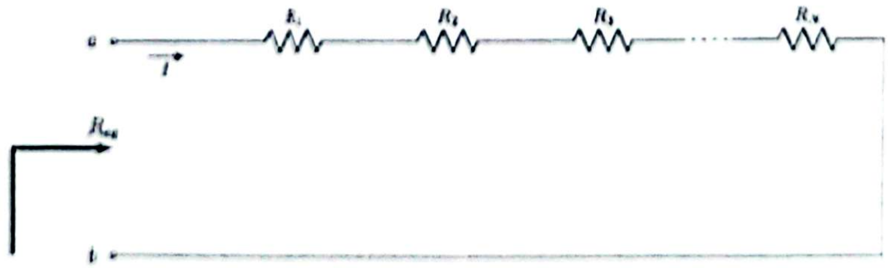


Figure: A series connection

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 is, $\Delta V = V_a - V_b$. Hence, we conclude that the resistors are connected in parallel. The equivalent resistance of these resistors is R_{eq} where,

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

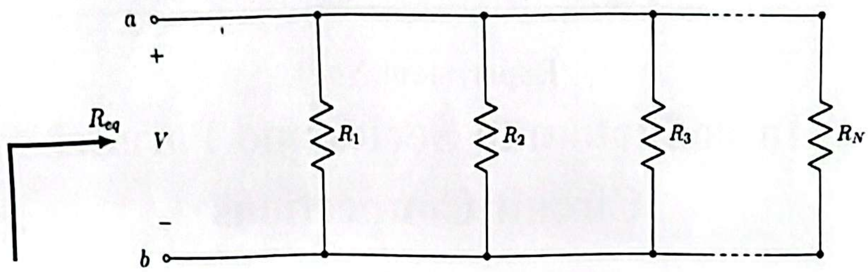


Figure: A parallel connection

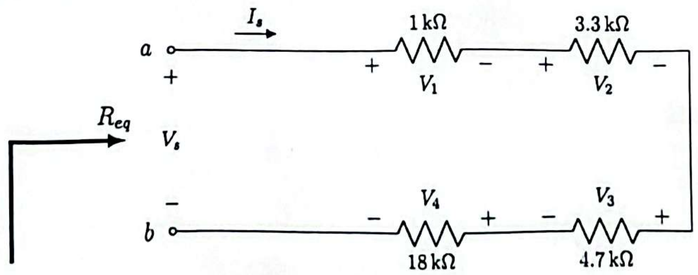
In this experiment, we will learn how to connect circuits on breadboards and how to identify series and parallel connections,

Apparatus

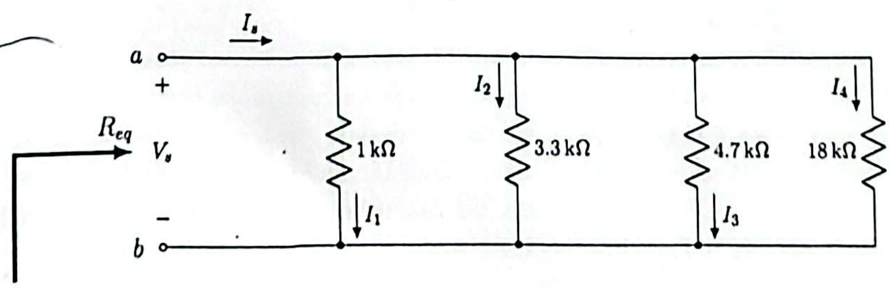
- Multimeter
- Resistors
- DC power supply
- Breadboard
- Jumper wires

Procedures

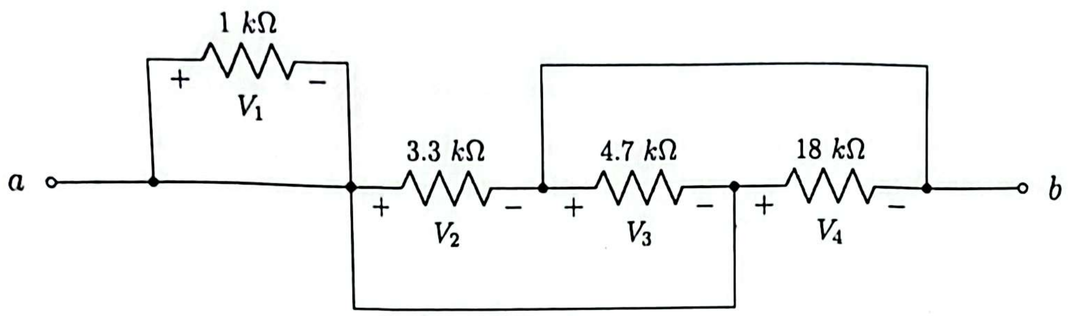
- Measure the resistances of the provided resistors and fill up the data table.
- Construct the following circuits on a breadboard. Try to use as less number of jumper wires as possible.



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 resistor. Use multimeter to measure 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: Tasnim **Date:** 05.11.24

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

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	0.987 kΩ
R_2	3.3 kΩ	3.267 kΩ
R_3	4.7 kΩ	4.60 kΩ
R_4	18 kΩ	17.65 kΩ

Table 1: Data from Circuit 1

In the following table, V_1 is the voltage drop across the resistor R_1 and I_1 is the current through it. A similar syntax applies to remaining resistors. **For theoretical calculations, please note that, in a 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	26.51	6.0	6.06	0.23	0.225	0.228	0.744	0.228	1.051	0.228	4.03	0.228
Theoretical	27	[redacted]		0.22	0.22	0.22	0.74	0.224	1.05	0.22	4.03	0.22

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

Here, Percentage of error in R_{eq} calculation = 1.81 %

Table 2: Data from Circuit 2

In a parallel connection, all the voltage drops are the 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	.628	6.0	5.95	9.47	6.028	1.821	1.29	0.337
Theoretical	.641	[redacted]		9.35	5.95	1.81	1.27	0.33

Here, Percentage of error in R_{eq} calculation = 2.88 %

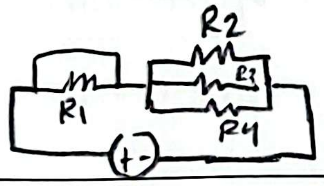
Table 3: Data from Circuit 3

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	1.728	6.0	6.05	3.5	0.0021	6.13	6.02	1.85	-6.04	1.32	6.03	0.34
Theoretical	1.75			3.46	0	0	6.05	1.83	6.05	1.29	6.05	0.33

Here, Percentage of error in R_{eq} calculation = 1.26 %

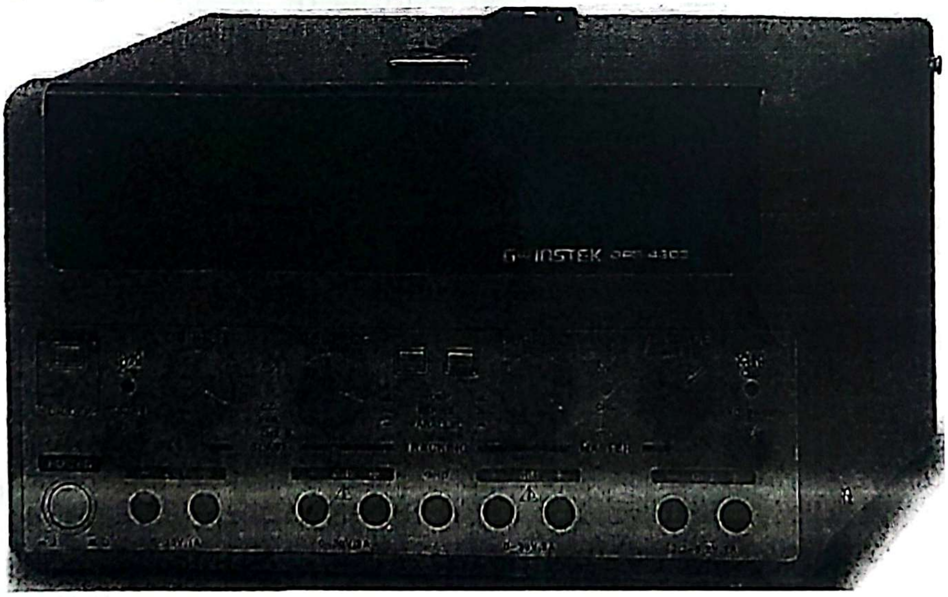
How are the resistors in circuit 3 connected? Justify your answer.



Here R_1 is short circuited and from the experimental data R_2, R_3 R_4 have quite similar voltage thus in parallel.

Questions

1. Refer to the following illustration of the **Linear DC Power Supply** you used in the laboratory to answer the following questions–



(a) Which of the operational modes of the power supply did you use for this experiment?

☑ Constant Voltage (C.V.) ☐ Constant Current (C.C.)

(b) If you are to take a voltage equal to 7 V, which of the channels can you use? Select all that apply–

☐ CH1 ☑ CH2 ☑ CH3 ☐ CH4

(c) Based on the Channels Selector feature, which pair of channels are we unable to use simultaneously? Select all that apply–

☑ CH1 & CH2 ☑ CH1 & CH3 ☑ CH1 & CH4 ☐ CH2 & CH3

☐ CH2 & CH4 ☐ CH3 & CH4

(d) Can we get a single negative voltage (say $-7\ V$) from the power supply?

☑ Yes ☐ No

If yes, how?

we will connect the positive output of the supply to the ground on our circuit and the negative output on the supply to the high side of the circuit

(e) Can we get two unequal negative voltages (say $-7\ V$ and $-3\ V$) from the power supply?

☑ Yes ☐ No

If yes, how? If not, why?

if the two channel of the power supply share the same ground then it is possible

(f) Check the squares adjacent to each of the following statements to indicate whether it is true or false:

I. The bigger voltage and current knobs correspond to CH1 and CH2.

☑ True ☐ False

II. The smaller voltage knobs are used to set voltages for CH3 and CH4.

☑ True ☐ False

III. The current knobs are used to limit the maximum current corresponding to the channels.

☑ True ☐ False

IV. The voltage displays show only the voltages set in CH1 and CH2.

☐ True ☑ False

V. The current displays show only the maximum current limit set in CH1 and CH2.

☐ True ☑ False

VI. Can this source be used as a constant current for applications such as recharging a battery?

☑ True ☐ False

VII. We can only set the maximum current limit for CH1 and CH2.

☑ True ☐ False

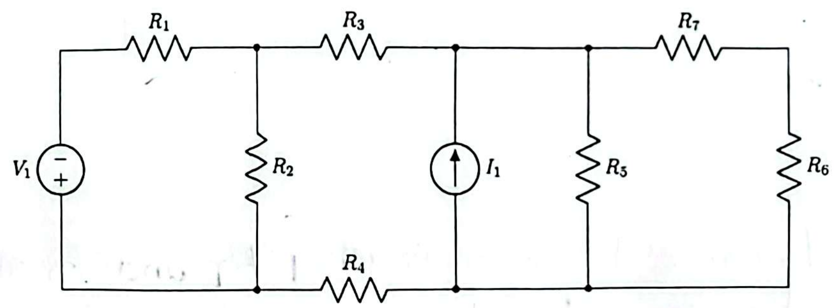
VIII. The maximum current limit for CH3 and CH4 is 1 A and is not tunable.

☑ True ☐ False

IX. Pressing the "Output On" button makes the current values displayed equal to 0. It means the source is not supplying any current to the circuit connected to it.

☐ True ☑ False

2.



(a) After taking voltage and current 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.

R4 and R7 resistors are not connected by any common terminal

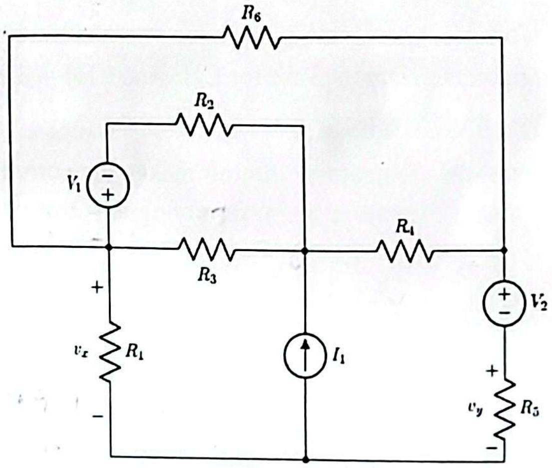
(b) R_1, R_2, and, R_3 are connected in

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

Explain your choice.

more than 12 terminals are connected on the same node.

3.



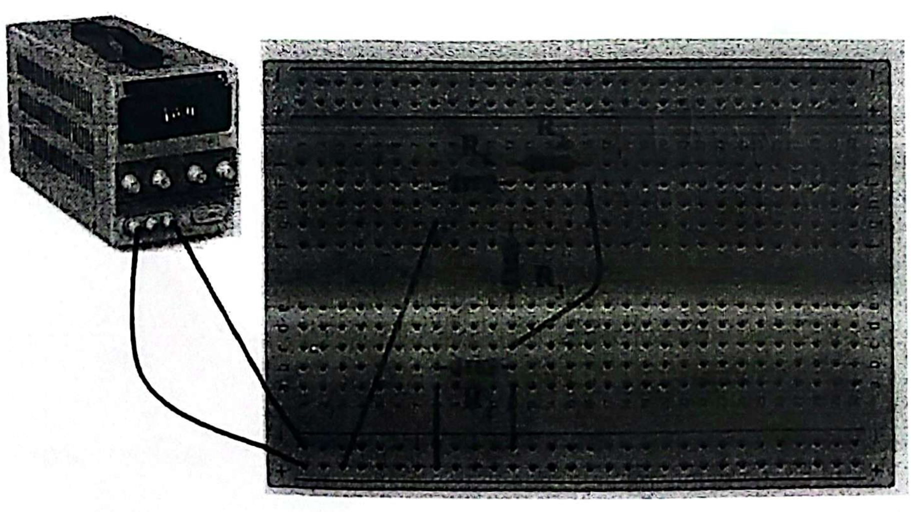
(a) If the voltages v_x and v_y are equal, are R_1 and R_5 in parallel?

☐ Yes ☑ No

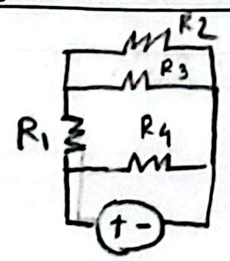
Justify your answer.

because to be in parallel R_1 and R_5 should be connected to the same terminal in one end and also to another terminal on the other end.

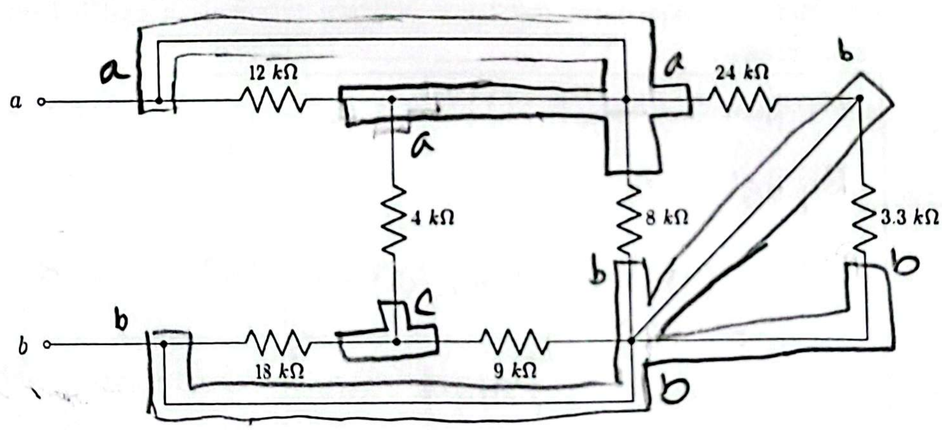
4.



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



5. For the following circuit:



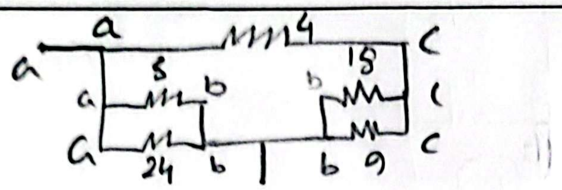
(a) How many nodes are there? Mark and label all the nodes in the circuit diagram.

3

(b) Using the node labels in (a) fill out the table below by inputting the starting and ending nodes for each row that are connected to the corresponding circuit element.

Circuit Element	Starting/Ending Node	Ending/Starting Node
12 kΩ Resistor	a	a
4 kΩ Resistor	a	c
18 kΩ Resistor	b	c
9 kΩ Resistor	b	c
8 kΩ Resistor	a	b
24 kΩ Resistor	a	b
3.3 kΩ Resistor	b	b

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



Hene, 12kΩ and 3.3kΩ resistors are shorted

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

$R_{15\|9} = (15^{-1}+9^{-1})^{-1} = 6k\Omega$

$R_{4+6} = 10k\Omega$

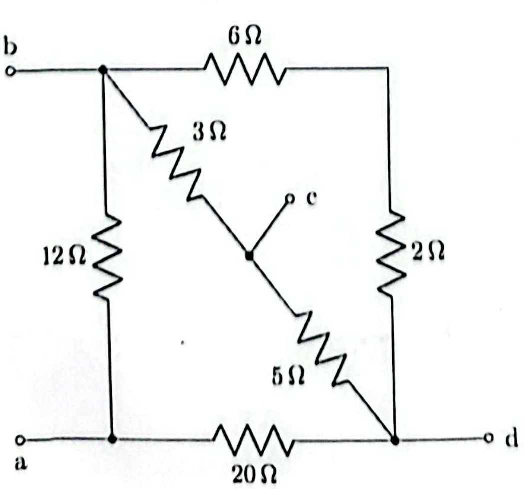
$R_{eq} = (10^{-1}+8^{-1}+24^{-1})$

$= 3.75\,\Omega$

(Ans)

6. For the following circuit, determine R_{ab}, R_{ad}, R_{bd} and R_{bc}. Use logical operators to indicate the series-parallel combinations. For example, 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.

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



$R_{ab} = [\{(6+2)\|\|(3+5)\}+20]\|\|12$ $= 8\Omega$	$R_{ad} = [\{(6+2)\|\|(3+5)\}+12]\|\|20$ $= 8.889\ \Omega$
$R_{bd} = \{(6+2)\|\|(12+20)\}\|\|(3+5)$ $= 3.55\Omega$	$R_{bc} = [\{(6+2)\|\|(12+20)\}+5]\|\|3$ $= 2.375\ \Omega$

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]*.

The overall experience was quite exciting for me. This was the first time I implemented series parallel connection on the breadboard. Getting to know the dc power supply was quite informative.

The measured data was quite accurate as the dc power supply output were stable. Resistance on the breadboard were connected tightly and the multimeter provided stable data. I did faced some difficulties as this was the 1st time but the lab instructors were quite helpful. Overall it was a good experience made the theoratical part more clear