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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,

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

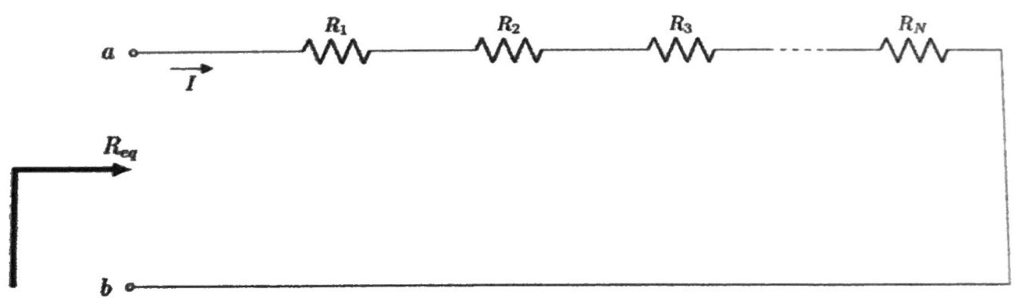


Figure: A series connection

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,

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

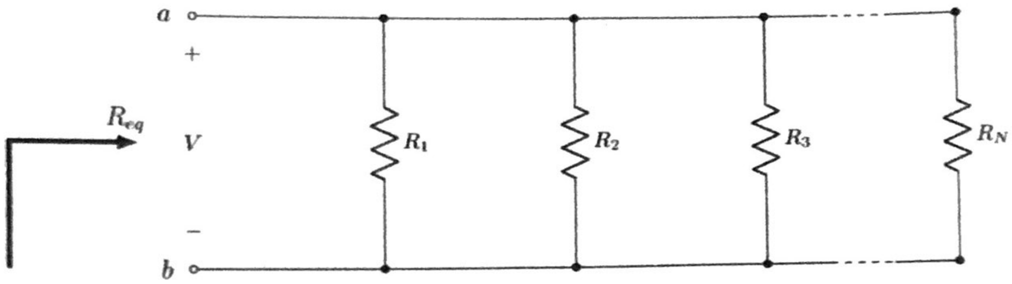


Figure: A parallel connection

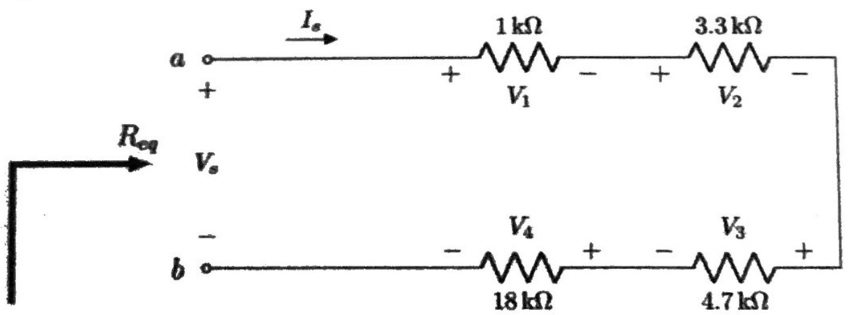
In this experiment, we will learn how to connect circuits on breadboards and how to identify series and parallel connections,

Apparatus

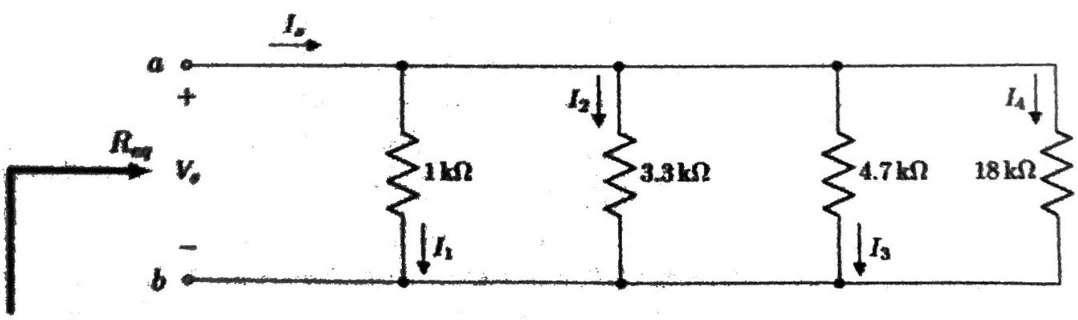
- Multimeter
- Resistors
- DC power supply
- Breadboard
- Jumper wires

Procedures

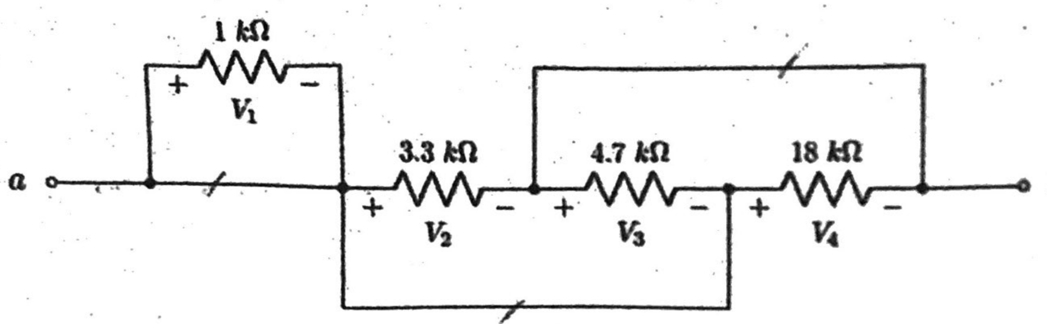
- Measure the resistances of the provided resistors and fill up the data table.
- Construct the following circuits on a breadboard. Try to use as less number of jumper wires as possible.



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: [signature] **Date:** 3-11-24

** ***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	1.000 kΩ
R_2	3.3 kΩ	3.247 kΩ
R_3	4.7 kΩ	4.66 kΩ
R_4	18 kΩ	17.87 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	26.77	6.00	6.09	0.227	0.2275	0.2275	0.739	0.2276	1.064	0.2283	4.06	0.2272
Theoretical	26.777			0.227	0.227	0.227	0.737	0.227	1.058	0.227	4.056	0.227

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

Here, Percentage of error in R_{eq} calculation = 0.026 %

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	0.631	6.00	6.07	9.619	6.07	1.869	1.302	0.340
Theoretical	0.634			9.574	6.07	1.869	1.303	0.339

Here, Percentage of error in R_{eq} calculation = 0.473 %

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	1.732	6.00	6.08	3.510	0.001	0.001	6.07	1.869	-6.07	-1.302	6.08	0.340
Theoretical	1.729			3.516	0	0	6.07	1.869	-6.07	-1.303	6.08	0.340

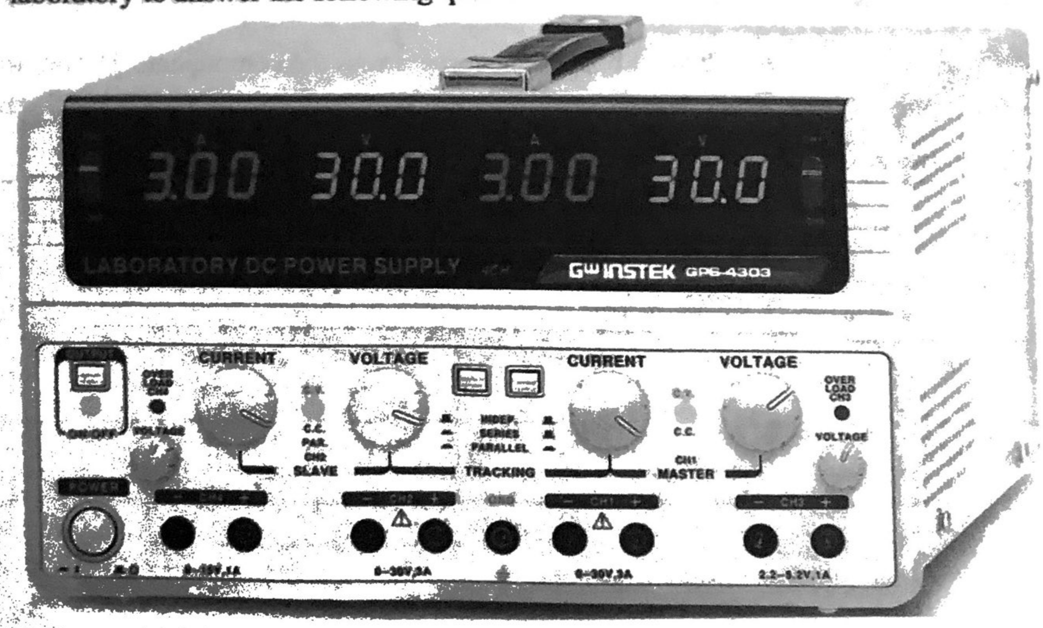
Here, Percentage of error in R_{eq} calculation = 0.174 %

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

The resistors R2, R3 and R4 are connected in parallel. There is no current flow in R1 as it is connected through a short circuit.

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, voltages for which pair of channels are we unable to display 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?

In order to get negative voltage we connect it with either the CH1 or CH2 channel and set the voltage to 7V. Then we switch the positive and negative probe to get -7V.

(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?

we first set CH1 to 7V and set CH2 channel to 3V. Then we switch the probes for each channel from the positive to negative probe to get -7V and -3V.

(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

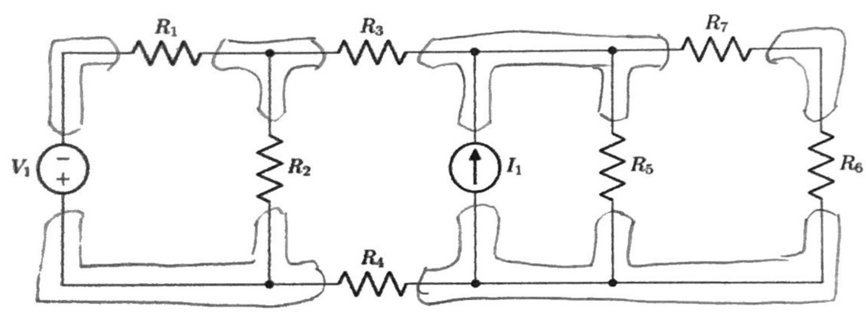
VIII. The maximum current limit for CH3 and CH4 is 1 A and is not tunable.

☑ 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.

Since the resistors R4 and R7 are part of different nodes and do not share any common point. Hence, they are not in series.

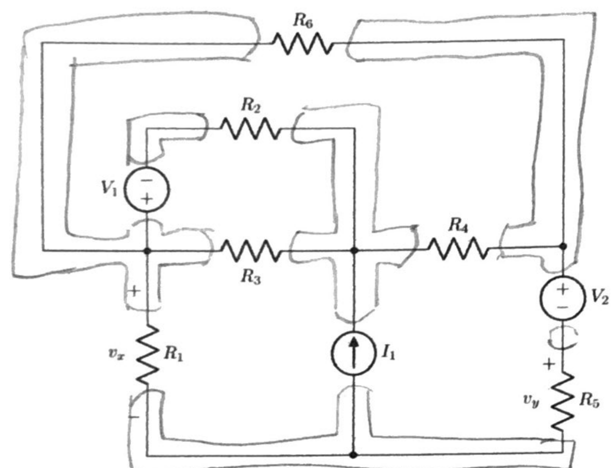
(b) R_1, R_2, and, R_3 are connected in

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

Explain your choice.

Since the resistors R1, R2 and R3 are part of the same node but do not share a common line so, they are not in series. The resistors also dont have 2 common nodes so they are not parrallel. Hence, the connection cannot be predicted.

3.



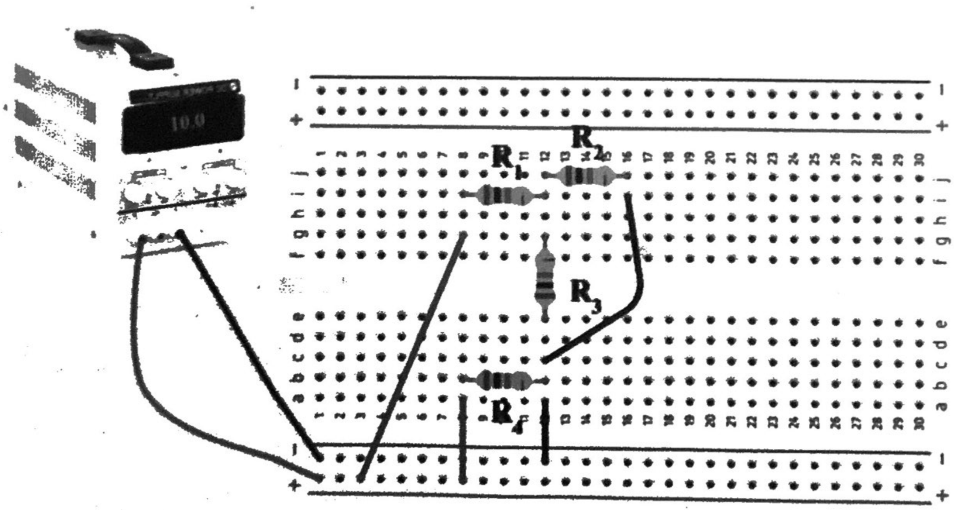
(a) If the voltages v_x and v_y are equal, are R_1 and R_5 in parallel?

☐ Yes ☑ No

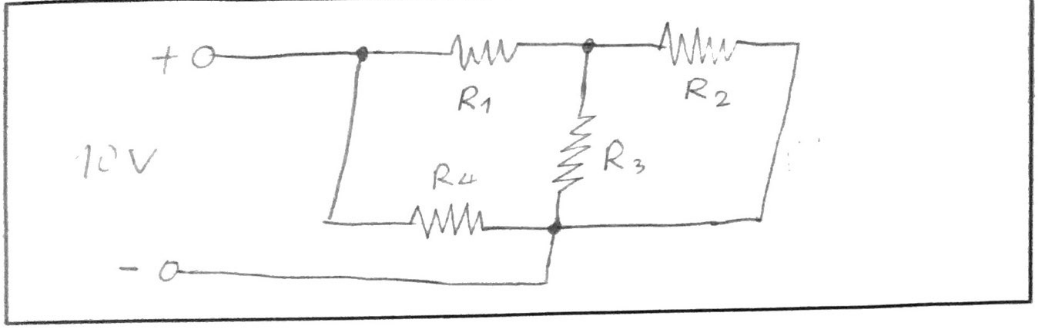
Justify your answer.

Since R1 and R5 only share 1 common node instead of 2 common nodes so they are not parallel.

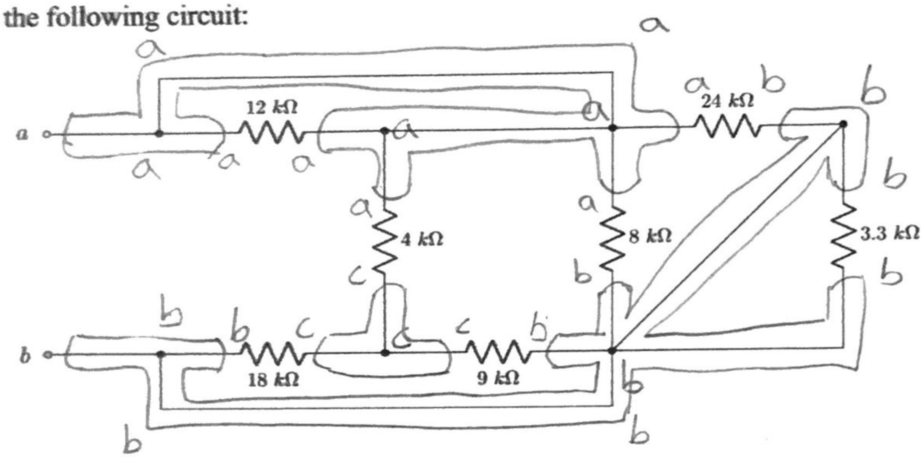
4.



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



5. For the following circuit:



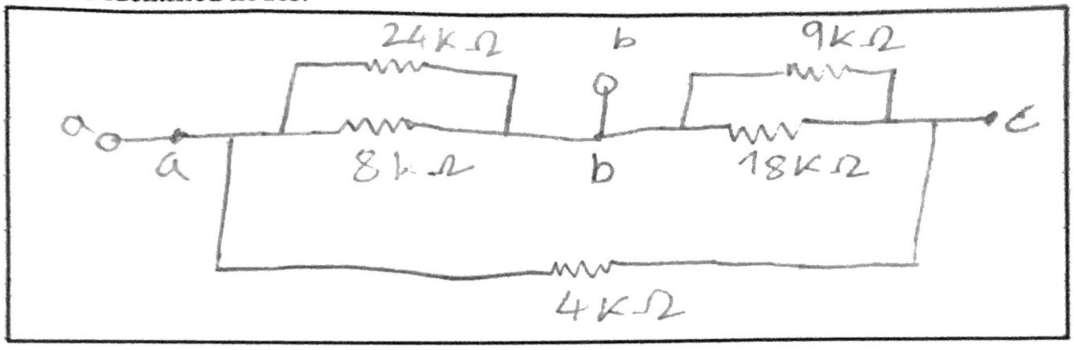
(a) How many nodes are there? Mark and label all the nodes in the circuit diagram.

3 Nodes

(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	c	b
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.



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

∴ 18KΩ and 9KΩ in parallel :-

$\frac{1}{R_1} = \frac{1}{18} + \frac{1}{9} \Rightarrow R_1 = (\frac{1}{18} + \frac{1}{9})^{-1} = 6k\Omega$

∴ R_1 and 4KΩ in series :-

$R_2 = 6 + 4 \Rightarrow R_2 = 10k\Omega$

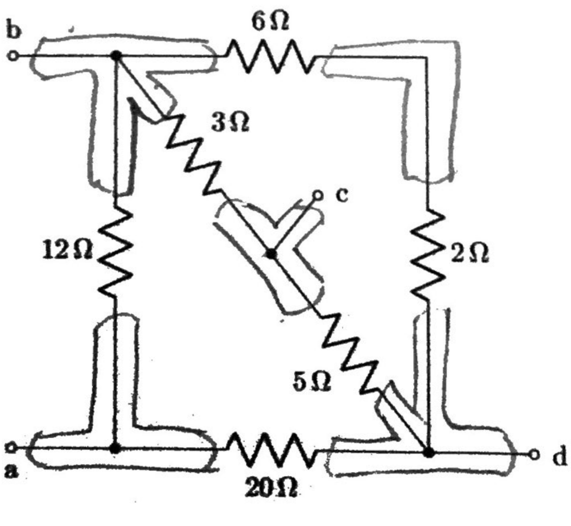
∴ R_2, 24 KΩ and 8kΩ in parallel :-

$\frac{1}{Req} = \frac{1}{10} + \frac{1}{24} + \frac{1}{8} \Rightarrow Req = (\frac{1}{10} + \frac{1}{24} + \frac{1}{8})^{-1} = 3.75k\Omega$

$\Rightarrow Req = 3.75\ k\Omega$

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.

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



$R_{ab} = [\{(6+2) \| (3+5)\} + 20] \| 12$ $= 8\,\Omega$	$R_{ad} = [12 + \{(3+5) \| (6+2)\}] \| 20$ $= 8.89\,\Omega$
$R_{bd} = (3+5) \| (6+2) \| (12+20)$ $= 3.56\,\Omega$	$R_{bc} = [\{(6+2) \| (12+20)\} + 5] \| 3$ $= 2.38\,\Omega$

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].***

∴ Discussion

The lab involved using a multimeter to find the equivalent resistance as well as the current and voltage of specific circuits. The value of the resistance for the resistors varry from the expected values due to errors in production ~~error~~ or errors in measurements which might lead to inaccuracies. Difficulities might include the proper placement of the circuit elements into their proper positions in the breadboard due to faultiness in the hardware components or breadboard strips or while using the multimeter to find the proper resistance while minimizing errors as much as posible and avoid human errors in the measurements. These difficulities can be avoided through more practice dealing with circuits.