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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,

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

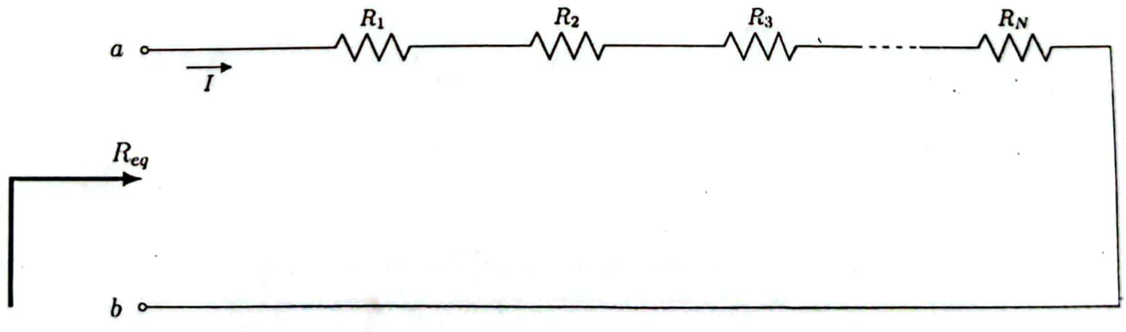



Figure: A series connection

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,

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

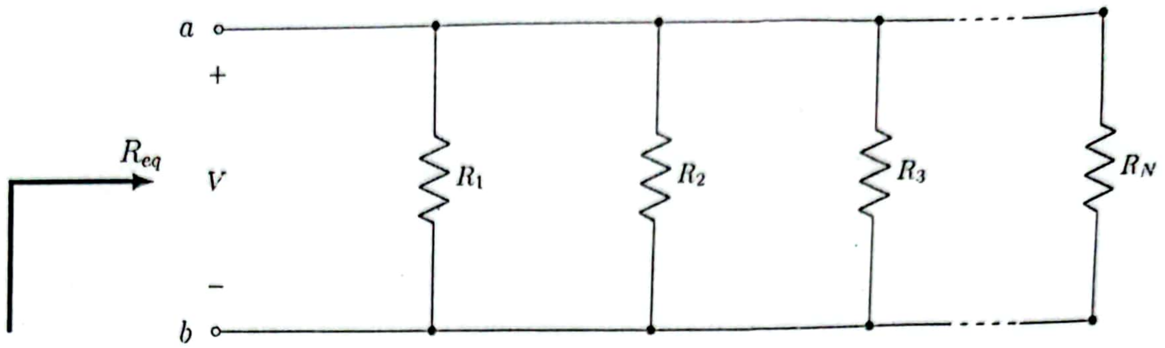



Figure: A parallel connection

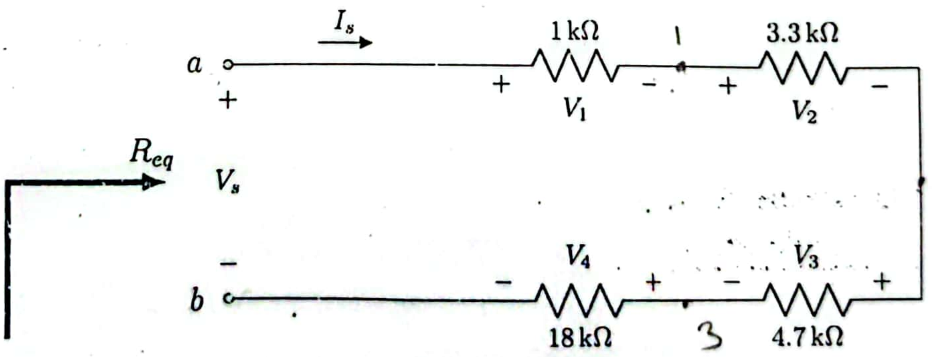
In this experiment, we will learn how to connect circuits in breadboards and how to identify series and parallel connections,

## Apparatus

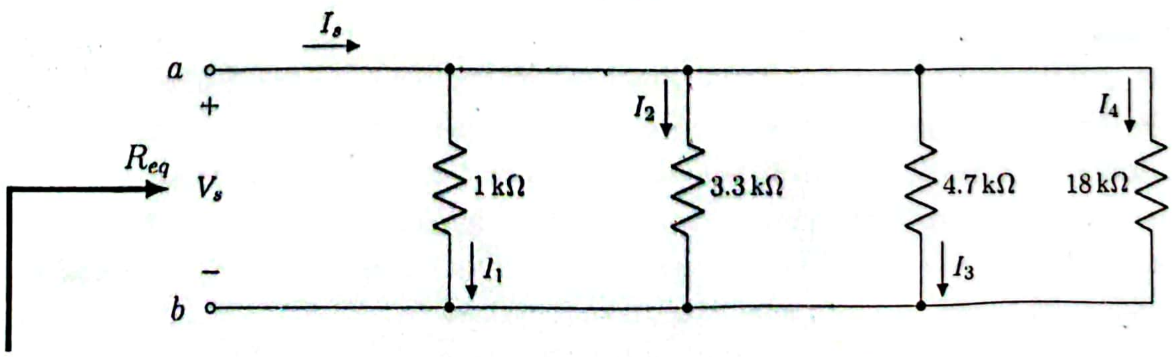
- Multimeter
- Resistors
- DC power supply
- Breadboard
- Jumper wires

## Procedures

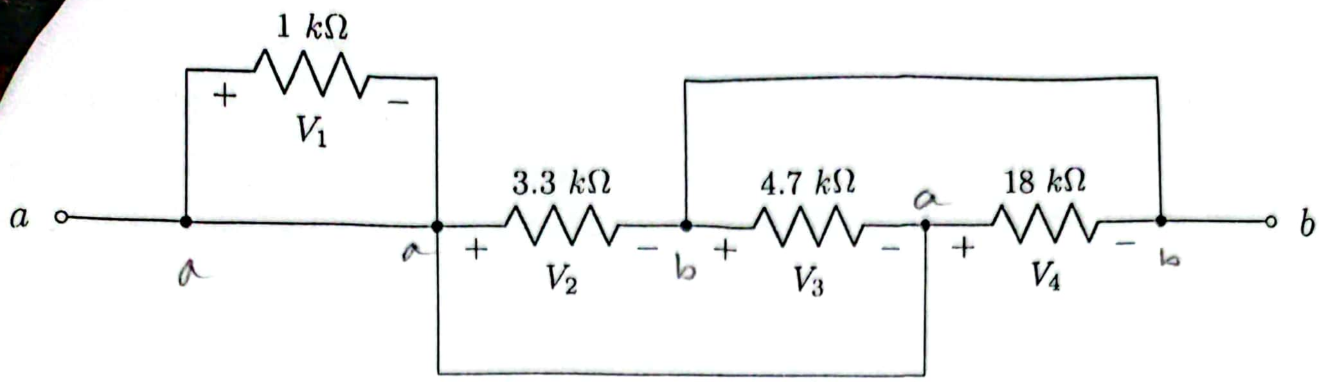
- Measure the resistances of the provided resistors and fill up the data table.
- Construct the following circuits on a breadboard. Try to use minimum number of jumper wires:




**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:**      **Date:** 08-10-20

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* ***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 | 1.00KΩ |
| $R_2$ | 3.3 kΩ | 3.275KΩ |
| $R_3$ | 4.7 kΩ | 4.61 |
| $R_4$ | 18 kΩ | 17.81 |

## Table 2: Data from Circuit 1

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 | 26.66 | 6.0 | 6.02 | 0.2258 | 0.2209 | .2209 | 0.732 | .2235 | 1.038 | 0.2252 | 4.02 | 0.2257 |
| Theoretical | 26.29 | | 6 | 0.228 | 0.222 | 0.227 | 0.738 | 0.227 | 1.0442 | 0.227 | 3.99 | 0.227 |

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

Here, Percentage of error in $R_{eq}$ calculation = 1.407 %

## 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 | 0.635 | 6.0 | 5.98 | 9.417 | 5.98 | 1.826 | 1.297 | 0.336 |
| Theoretical | 0.619 | | 6 | 9.693 | 6 | 1.81 | 1.27 | 0.33 |

Here, Percentage of error in $R_{eq}$ calculation = 9.69 %

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## Table 4: Data from Circuit 3

Collect the following data.

| Operation | $R_{ab}$ (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 | 1.73 | 6 | 6.02 | 3.48 | 0.0035 | 0.0035 | 6.01 | 1.835 | -6.01 | -1.302 | 6.01 | 0.337 |
| Theoretical | 1.75 | 6 | 6 | 3.49 | 0 | 0 | 6 | 1.81 | 6 | 1.27 | 6 | 0.33 |

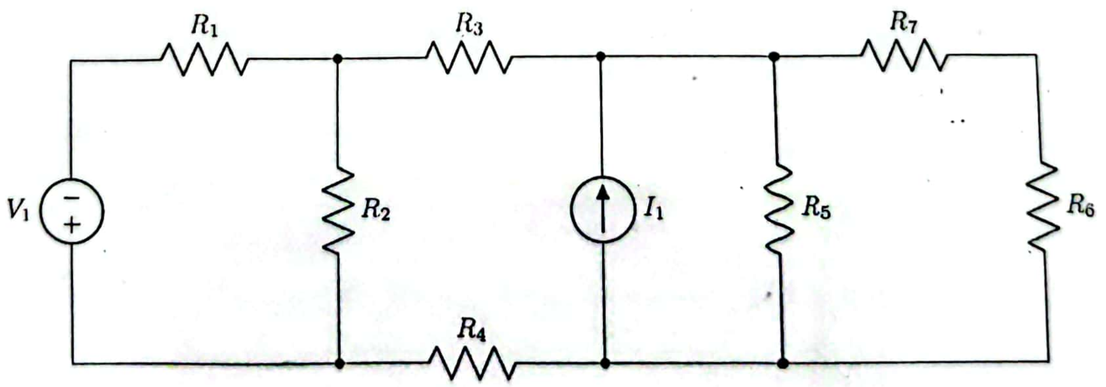
Here, Percentage of error in $R_{eq}$ calculation = 1.08 %

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 combitation

## 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.

Using mesh analysis $\in I_1 \to R_1$, $i_2 \; \frac{-I_2 R_3 + I_2 R_4}{R_3 + R_3 - R_2}$
And $C1 \to R_3$ is $i_4 = \frac{I_1 R_3}{R_1 + R_3}$
Hence, we see that $i_2$ and $i_4$ are different although they might be equal but that doesn't are in series combination

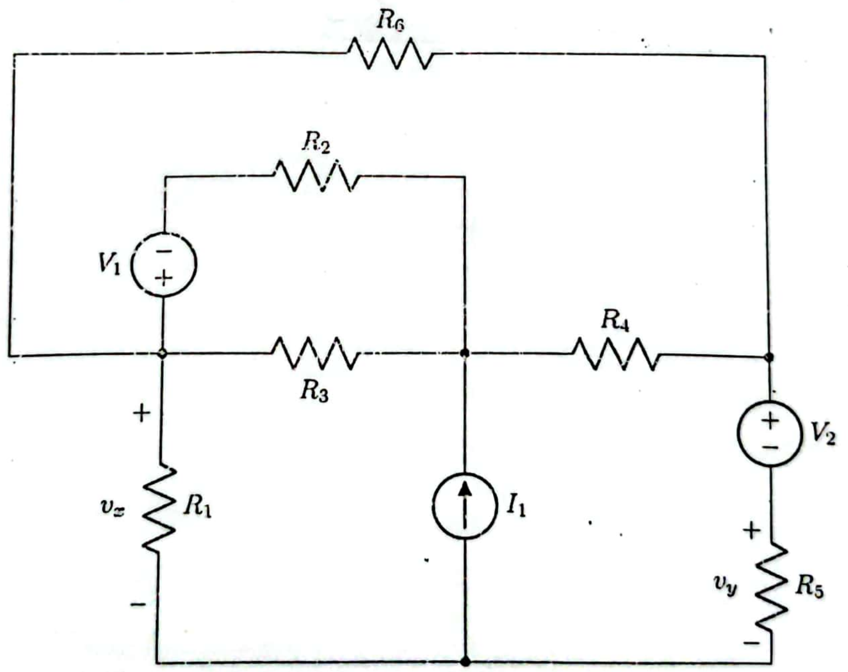
(b) $R_1$, $R_2$, and, $R_3$ are connected in

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

Explain your choice.

R1, R2 and R3 are in mixture of both Parallel and series combination

**2.**

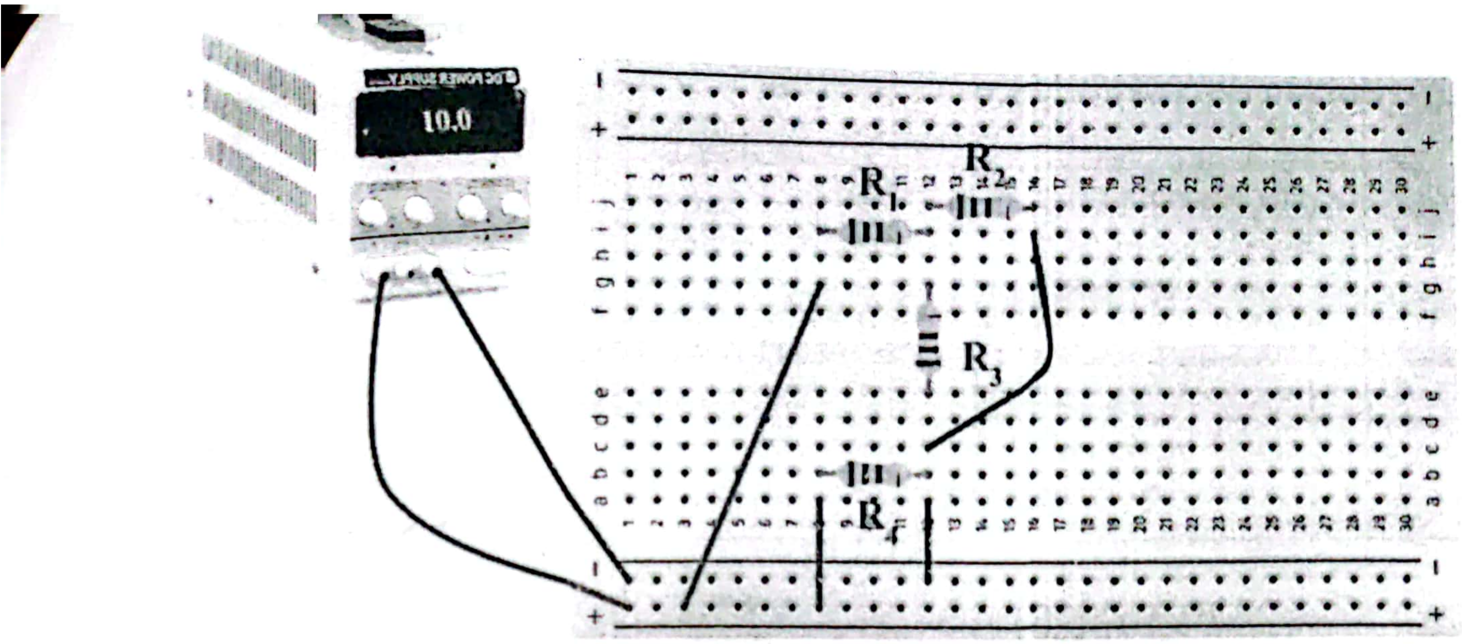



(a) If the voltages $v_x$ and $v_y$ are equal, are $R_1$ and $R_5$ in parallel?

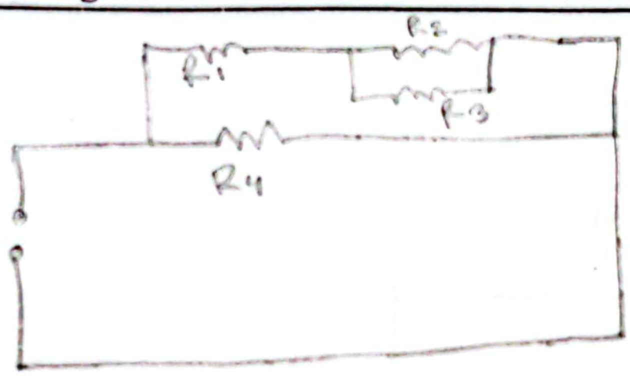
☐ Yes ☑ No

Justify your answer.

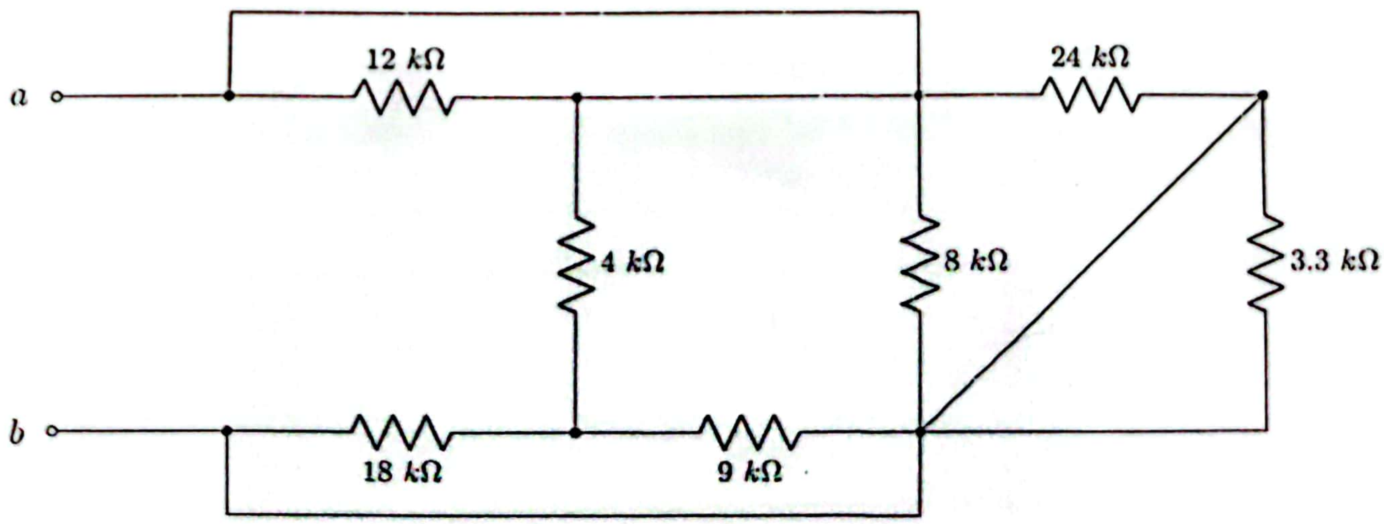
NO, R1 and R5 are not between some pair of nodes so they are not parallel




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




4. For the following circuit:



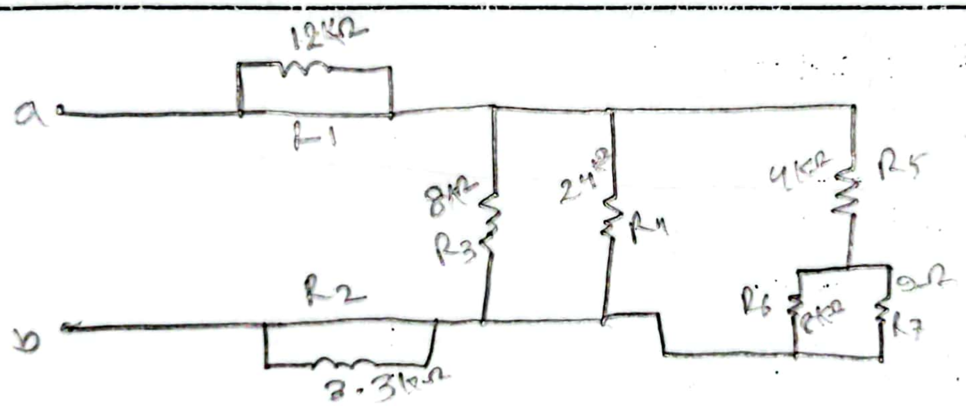

(a) How many nodes are there. Mark and label all the nodes in the circuit diagram.

4

ending nodes in each row that connect the corresponding circuit element.

| Circuit Element | Starting/Ending Node | Ending/Starting Node |
| --- | --- | --- |
| 12 kΩ Resistor | a | c |
| 4 kΩ Resistor | c | d |
| 18 kΩ Resistor | b | d |
| 9 kΩ Resistor | d | b |
| 8 kΩ Resistor | b | a |
| 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.



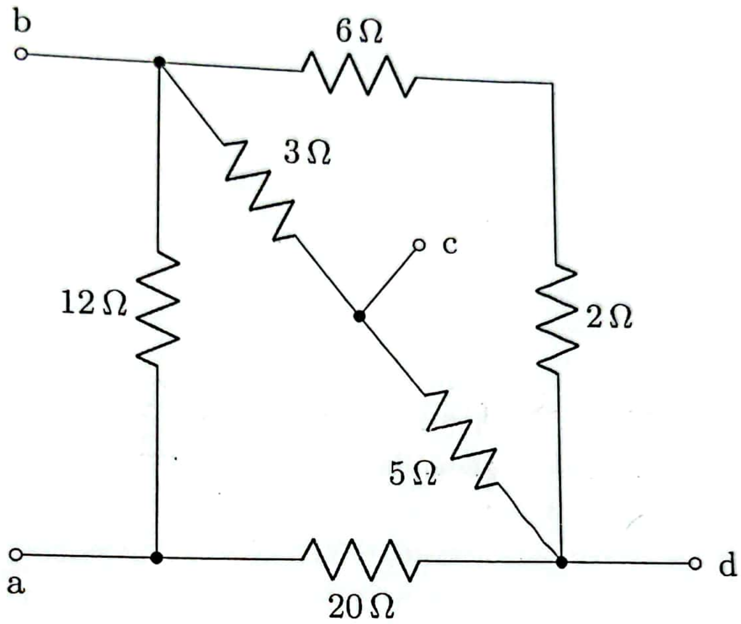

(d) Determine the equivalent resistance between terminals a and b from the reduced circuit drawn in (c).

$$R_{eq} = \left(\frac{1}{64} + \frac{1}{8}\right)^{-1}$$

$$= 6\ k\Omega$$

5. For the following circuit, determine $R_{ab}$, $R_{ac}$, $R_{ad}$, $R_{bd}$ and $R_{cd}$. Use logical operators to indicate the series-parallel combinations. For exmple, the following equation 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.

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




| | |
|---|---|
| $R_{ab} = \{(2+6) \,\|\|\, (5+3) + 20\} \,\|\|\, 12\,\Omega$ <br> $=$ | $R_{ac} = (12+3) \,\|\|\, (20+5)$ <br> $=$ |
| $R_{ad} = ((5+3) \,\|\|\, (5+3) + 12) \,\|\|\, 20$ <br> $=$ | $R_{bd} = (12+20) \,\|\|\, 8 \,\|\|\, 8$ <br> $=$ |
| $R_{cd} = ((20+12) \,\|\|\, (6+2) + 3) \,\|\|\, 5$ <br> $=$ | |

## 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.