BRAC UNIVERSITY
Dept. of Computer Science and Engineering

CSE250L
Circuits and Electronics Laboratory

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Experiment No. 4

Study of I-V Characteristics of Linear Circuits

Objective

This experiment aims to acquaint students with the concept of I-V characteristics. They will find I-V characteristics of some linear components and some circuits consisting linear combinations of them.

Part 1: By Using Multimeter

Theory

I-V characteristics, also known as current-voltage characteristics, describe the relationship between the current flowing through a device/circuitry and the corresponding potential difference (voltage) across it. This concept is commonly used in the field of electronics and electrical engineering to analyze the behavior of various components such as resistors, diodes, transistors, and in general, circuits.

I-V characteristics provide a way to understand how current and voltage interact in electrical and electronic components and circuits. By analyzing these characteristics, circuits/devices can be designed and optimized, appropriate components can be selected, and the behavior of devices under different operating conditions can be predicted.

In hardware labs, studying the I-V characteristics of an element/circuitry can be done in some simple steps. After building the circuit using hardware tools (such as Breadboards, Power Supply), a multimeter or other measuring instruments can be used to measure the voltage and current at specified terminals in the circuit. The multimeter probes can be placed across the component or along the desired path (specified by the terminals) to measure the voltage difference and current flow. To determine the I-V characteristics, the voltage or current across the circuit or specific components must be varied. This can be done by adjusting the power supply voltage, using variable resistors, or changing the values of other circuit parameters. As the voltage or current is varied and the corresponding values are measured, the data can be recorded in a table. The voltage and current values for each point of interest in the circuit should be noted.

Once we have the values of currents and voltages at various points in the circuit, the I-V characteristics can be plotted. Typically, this involves creating a graph with current (I) on the y-axis and voltage (V) on the x-axis.

A circuit is linear if its I-V characteristic is linear, represented by a straight line in an I versus V plot. A circuit composed of linear components (resistors, voltage sources, current sources) has a straight-line I-V characteristic.

For a simple resistor, the I-V characteristics follow Ohm's Law, which states that the current passing through a resistor is directly proportional to the voltage applied across it. Mathematically, this relationship can be expressed as $I = \frac{V}{R}$, where I is the current, V is the voltage, and R is the resistance. The characteristic line passes through the origin.

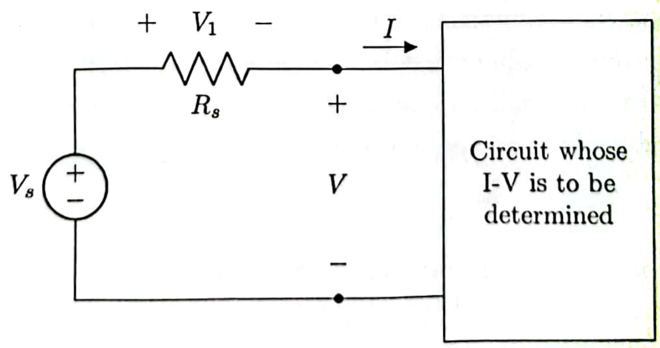
The I-V characteristic of an ideal voltage source (an ideal voltage source is a theoretical concept that maintains a constant voltage across its terminals, regardless of the current flowing through it.) is a vertical line on an I-V graph, indicating that the voltage remains constant (V) regardless of the current (I). Mathematically, it can be represented as $V = constant$. Real-life voltage sources (for example, DC power supply in our labs) do not exactly behave this way, but should closely resemble an ideal voltage source. Similarly, an ideal current source has an I-V line parallel to the voltage axis since it supplies a constant current with theoretically any voltages across.

Apparatus

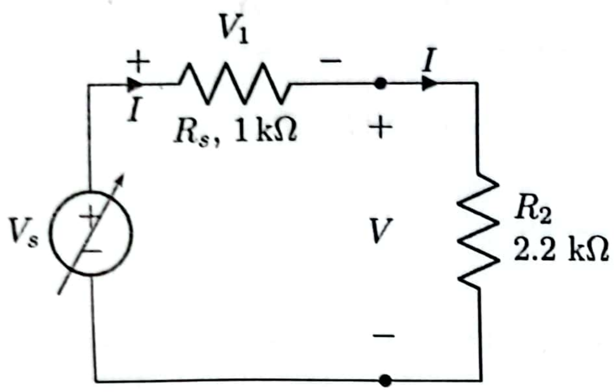
- Multimeter
- Resistors (1 kΩ x 2, 2.2 kΩ, 3.3 kΩ, 4.7 kΩ, 10 kΩ)
- DC power supply
- Breadboard
- Jumper wires

Procedures

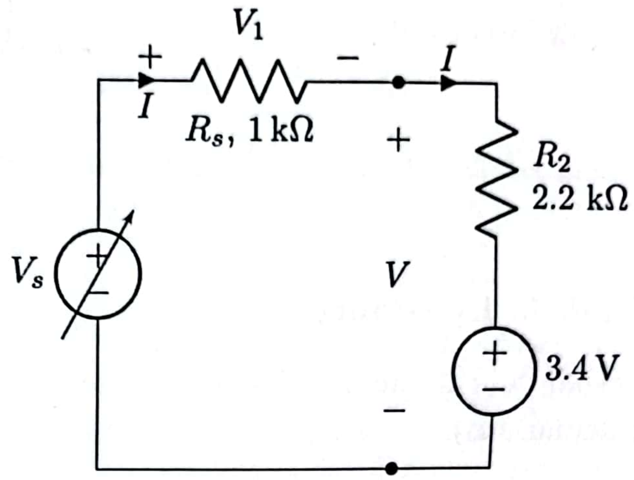
- Measure the resistances of the provided resistors and fill up Table 0.
- The following is the experimental setup we'll follow to derive $I - V$ characteristics of any circuit. Here, V_s is the applied voltage which is to be varied. The resistor R_s is used to facilitate the current measurement using Ohm's law as $I = \frac{V_1}{R_s}$. It is important to note that we have to plot I $vs.$ V.



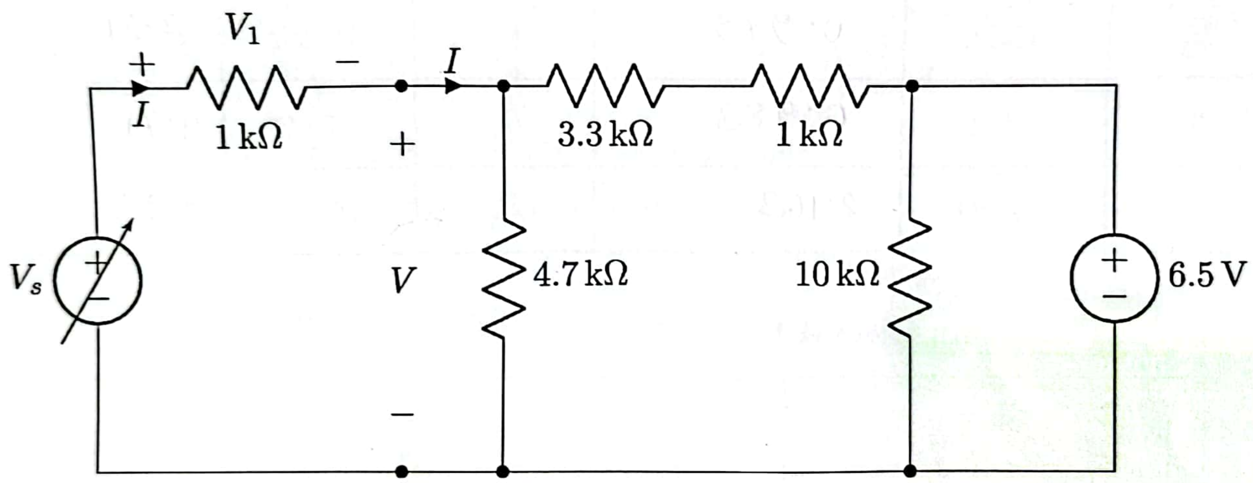
- Construct the following circuits on a breadboard. Try to use as less number of jumper wires as possible.



Circuit 1



Circuit 2



Circuit 3

- For each of these circuits, apply the specified supply voltages (from the first column of their respective data tables) using the DC power supply.
- Measure the voltage, V_1 across the 1 kΩ resistor using the multimeter and use Ohm's law to calculate the current I through the two terminals (denoted by • in the circuits).
- Measure the voltage, V across the two terminals (denoted by • in the circuits) using the multimeter, and fill up the data tables.

Data Tables

Signature of Lab Faculty: Sadik **Date:** 10/4/2025

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

Table 0: Resistance Data

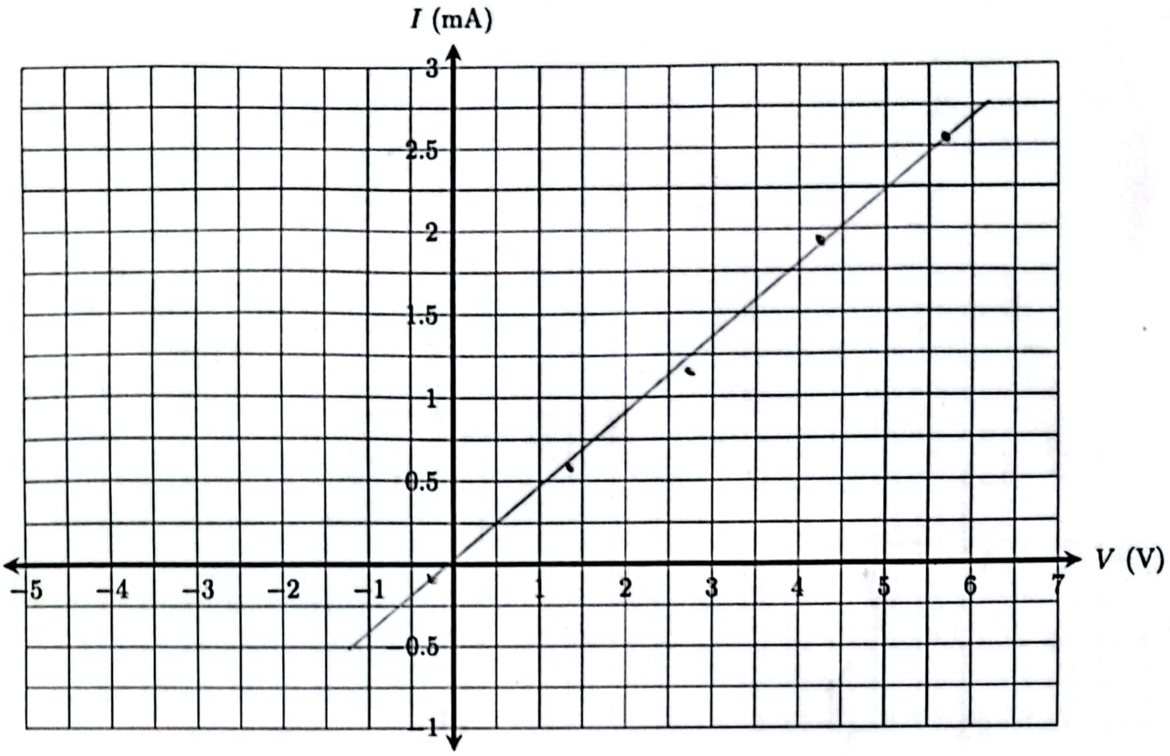
For all your future calculations, please use the observed values only **(even for theoretical calculations)**.

Notation	Expected Resistance	Observed Resistance (kΩ)	Notation	Expected Resistance	Observed Resistance (kΩ)
R_s	1 kΩ	0.979	R_3	3.3 kΩ	3.25
R_1	1 kΩ	0.983	R_4	4.7 kΩ	4.71
R_2	2.2 kΩ	2.163	R_5	10 kΩ	9.93

Table 1: Data from Circuit 1

V_S (V)			V_1 (V)		V (V)		$I = \frac{V_1}{R_s}$ (mA)	
Expected Voltage	From DC power supply	Using multi-meter	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical
0.0	0.0	-0.0035	-0.001	0	-0.0023	0	-0.0001	0
2.0	2.0	2.076	0.639	0.635	1.422	1.43	0.65	0.65
4.0	4.0	4.00	1.252	1.22	2.748	2.75	1.279	1.25
6.0	6.0	6.02	1.883	1.84	4.12	4.14	1.92	1.88
8.0	8.0	8.08	2.525	2.47	5.53	5.56	2.579	2.52

Plot the values of I and V from the above table.



Draw the best-fitting straight line through all the data points.

Slope of the straight line, m = 0·456 $k\Omega^{-1}$

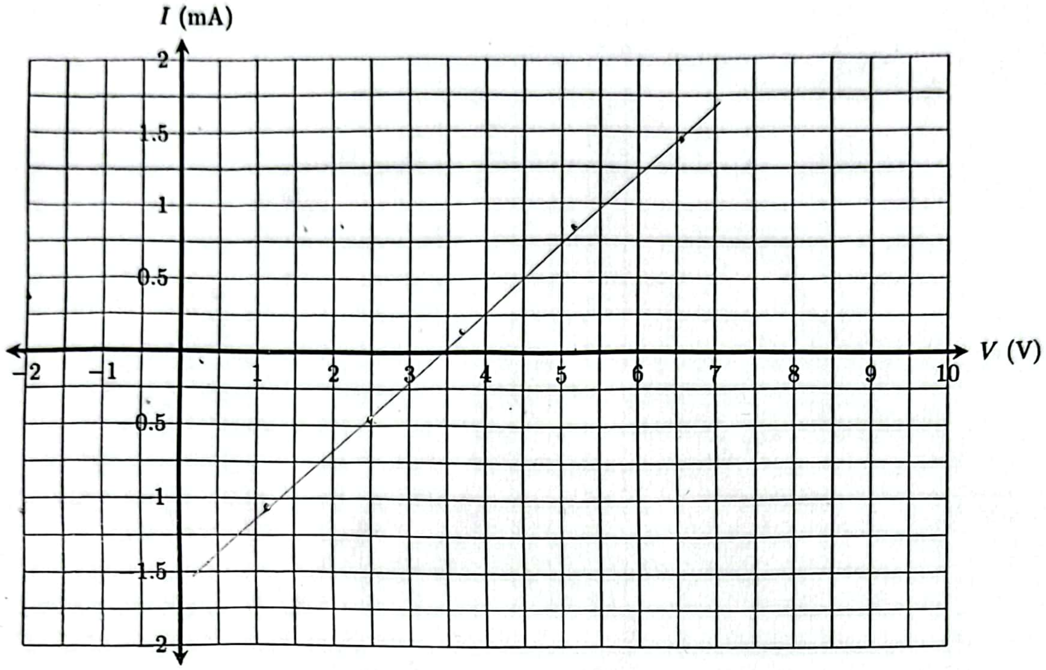
Resistance from the plot, $R_T = \frac{1}{m}$ = 2·19 $k\Omega$

Percentage of Error $= \left|\frac{R_2 - R_T}{R_2}\right| \times 100\%$ = 1·248 %

Table 2: Data from Circuit 2

V_S (V)			V_1 (V)		V (V)		$I = \frac{V_1}{R_s}$ (mA)	
Expected Voltage	From DC power supply	Using multi-meter	Experi-mental	Theo-retical	Experi-mental	Theo-retical	Experi-mental	Theo-retical
0.0	0·0	0·8	-1·083	-0·81	1·084	1·61	-1·106	-0·83
2.0	2·0	2·05	-0·49	-0·42	2·505	2·47	-0·45	-0·42
4.0	4·0	4·02	0·1749	0·19	3·83	3·83	0·18	0·19
6.0	6·0	6·06	0·805	0·83	5·25	5·23	0·82	0·85
8.0	8·0	8·08	1·442	1·46	6·65	6·62	1·47	1·49

Plot the values of I and V from the above table.



Draw the best-fitting straight line through all the data points.

Slope of the straight line, m = 0·46 $k\Omega^{-1}$

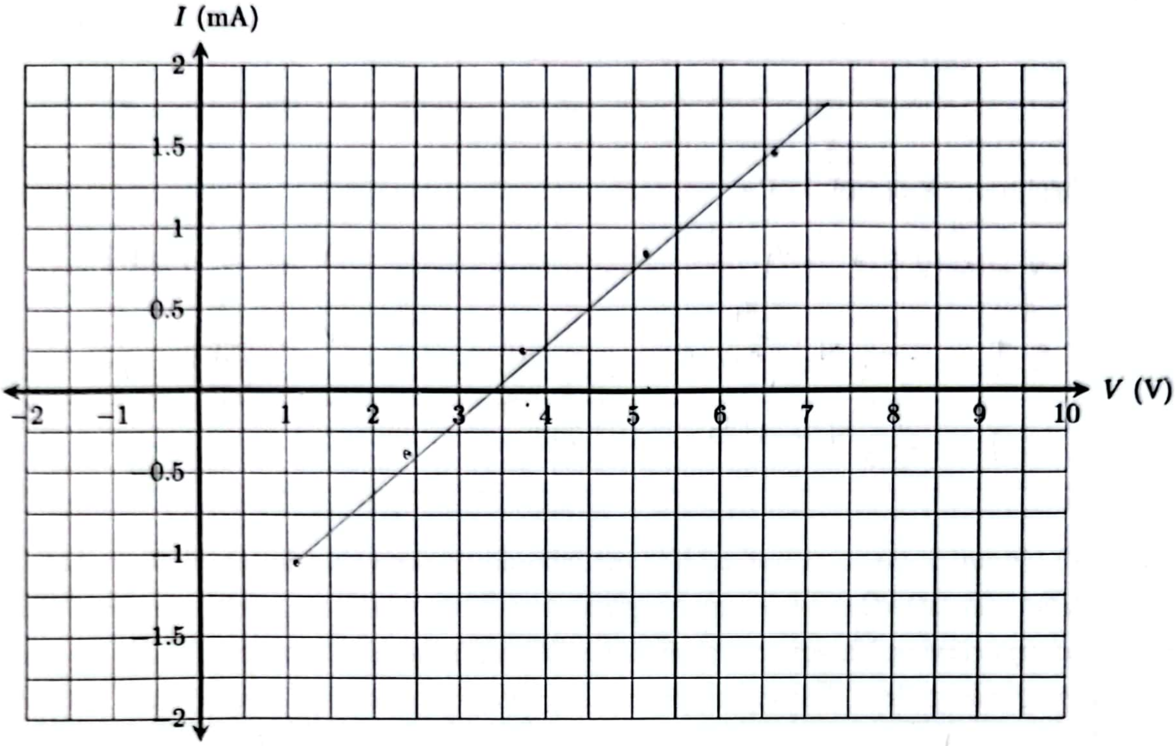
Resistance from the plot, $R_T = \frac{1}{m}$ = 2·17 $k\Omega$

The straight line intersects x-axis at, V_T = 3·5 V

Table 3: Data from Circuit 3

V_S (V)			V_1 (V)		V (V)		$I = \frac{V_1}{R_s}$ (mA)	
Expected Voltage	From DC power supply	Using multi-meter	Experi-mental	Theo-retical	Experi-mental	Theo-retical	Experi-mental	Theo-retical
0.0	0·0	-0·00	-1·059	-1·046	1·055	1·046	-1·08	-1·07
2.0	2·0	2·03	-0·435	-0·43	2·469	2·46	-0·444	-0·44
4.0	4·0	4·012	0·1698	0·16	3·81	3·852	0·17	0·16
6.0	6·0	6·00	0·781	0·7	5·22	5·3	0·798	0·72
8.0	8·0	8·07	1·412	1·41	6·65	6·66	1·44	1·44

Plot the values of I and V from the above table.



Draw the best-fitting straight line through all the data points.

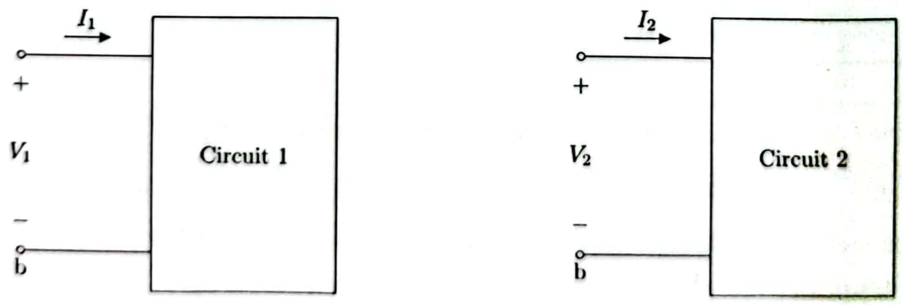
Slope of the straight line, m = 0·449 $k\Omega^{-1}$

Resistance from the plot, $R_T = \frac{1}{m}$ = 2·223 $k\Omega$

The straight line intersects x-axis at, V_T = 3·4 V

Questions

1. What conditions must exist for the following two circuits to be equivalent to each other with respect to terminals $a - b$?



~~2 conditions:~~
~~The I_1-V_1 relation and I_2-V_2 relation must be same~~
2 conditions: (i) $V_1 = V_2$, (ii) $I_2 = I_2$

2.

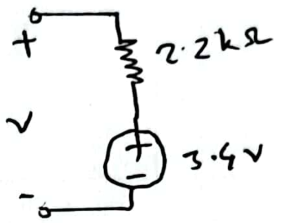
(a) For Circuit 2, you constructed it in the laboratory, derive a relation between I and V.
[Hint: Exclude the experimental setup part (left side of V) in Circuit 2. Your equation cannot contain any variables other than I and V]

Applying KVL at loop,

$V = 2.2I + 3.4$

$\Rightarrow I = \frac{1}{2.2}V - \frac{3.4}{2.2}$

$\therefore I = \frac{1}{2.2}V - 1.5$



(b) For Circuit 3, you constructed it in the laboratory, derive a relation between I and V.
[Hint: The 10 kΩ resistor can be ignored as it is parallel to a voltage source. Exclude the experimental setup part (left side of V) in Circuit 3 and try to reduce the circuit to a single loop first. Your equation cannot contain any variables other than I and V]

KCL at a,

$I = I_1 + I_2$

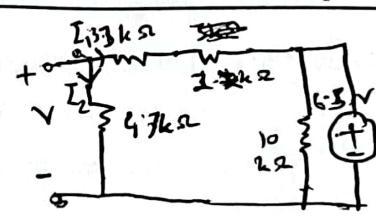
$\Rightarrow I_1 = I - \frac{V}{4.7}\ [I_2 = \frac{V}{4.7}]$

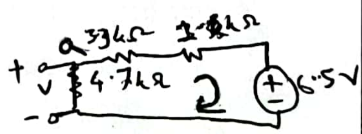
KVL at loop,

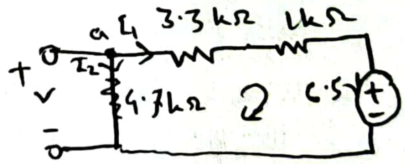
$-V + (3.3+1)I_1 + 6.5 = 0$

$\Rightarrow 4.3I - \left(\frac{4.3}{4.7}\right)V - V + 6.5 = 0$

$\Rightarrow I = 0.455V - 1.5$







(c) Do the $I - V$ equations derived in (a) and (b) closely match?

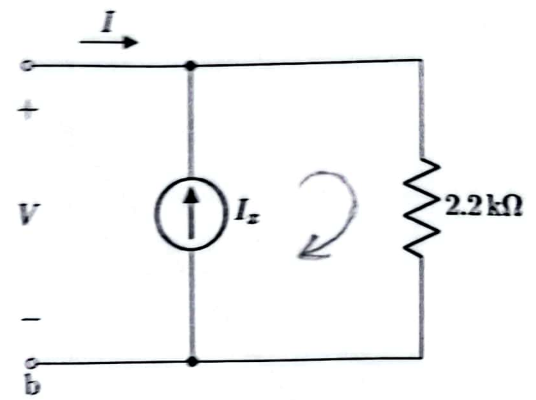
☑ Yes ☐ No

If yes, what conclusion can you draw from this, and will it have any effect if one of these two circuits is replaced with the other? Why??

Circuit-2 and circuit 3 can be substituted by each other without effecting performance as both have identical values.

(d) Now, for the following circuit, determine the value of I_x so that the $I - V$ relation matches with those you derived in (a) or (b). Is this circuit equivalent to Circuit 2 and Circuit 3?

[Hint: Derive a relation between I and V from this circuit. Then compare it with that in (a) or (b) to get i_x.]



KVL at loop,

$$2.2(I + I_x) - V = 0$$

$$\Rightarrow 2.2I + 2.2I_x = V$$

$$\therefore \Rightarrow I = \frac{1}{2.2} V - I_x$$

$$\therefore I_x = \frac{1}{2.2} V - I$$

if $I_x = 1.5$, the I-V relation matches with those derived in (a) or (b). The circuit will be equivalent.

3. Can you think of any way to measure the voltage-axis and current-axis intersecting points of the $I - V$ line of any linear circuit directly without even plotting the $I - V$ line?

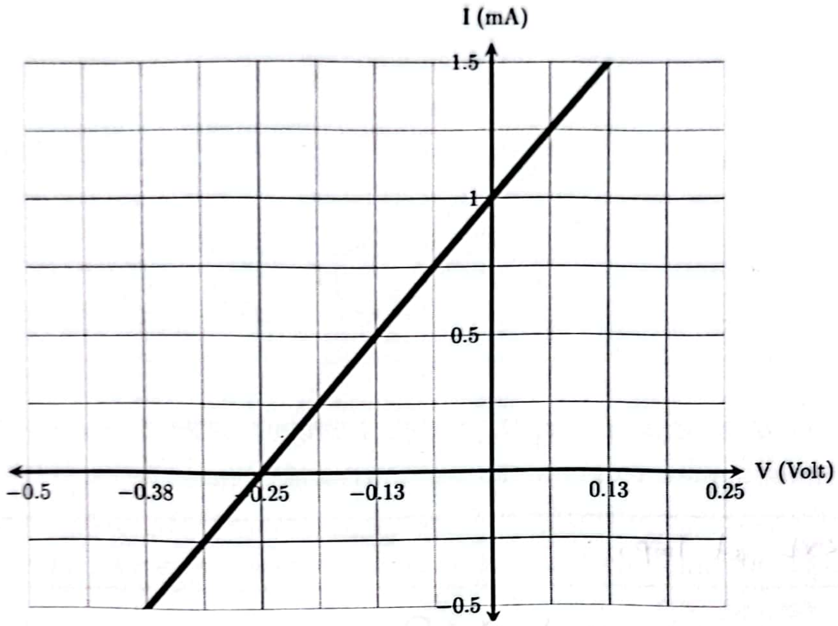
Yes

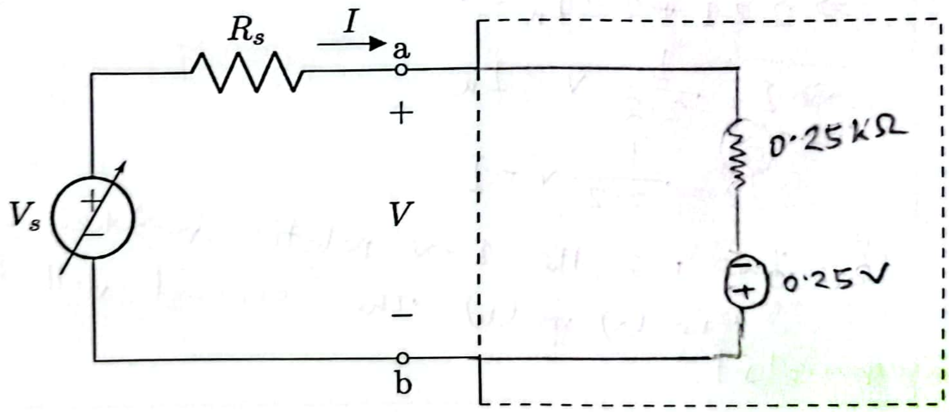
i. Measure the voltage across the circuit with no current (open circuit) ($I = 0$)

ii. Measure the current when terminals are short-circuited. ($V = 0$)

Ensures I-V line

4. A linear two-terminal circuit has the following $I - V$ relationship at the terminals $a - b$ measured in a laboratory with the setup shown below. Draw (inside the box) a simplified version of the circuit that can give rise to the same $I - V$ as shown. Also, write the corresponding values of the circuit elements.





Draw inside the dashed box