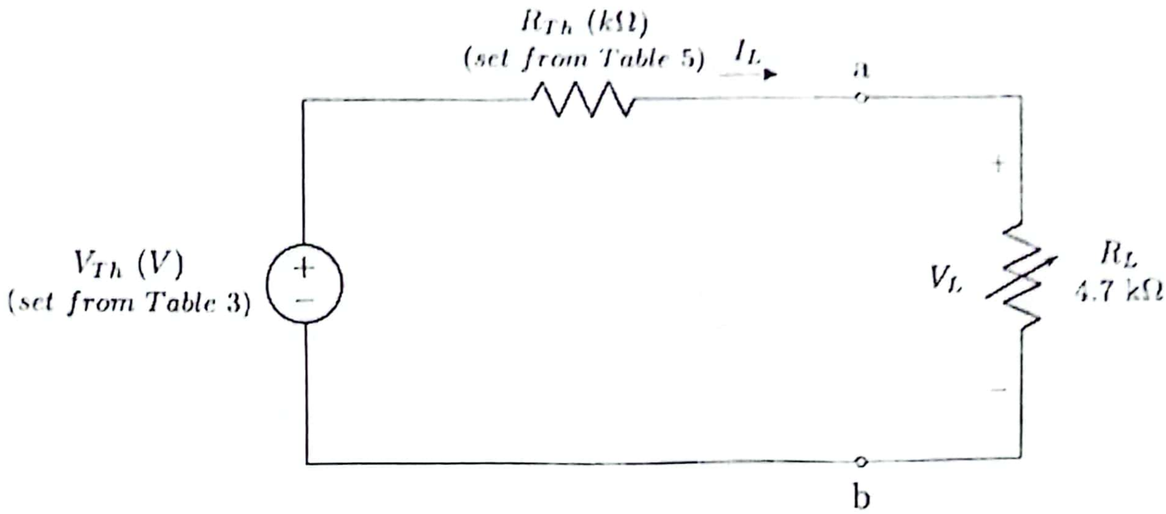


Circuit 5

➢ Measure the voltage (V_L) across the load resistance. Measure the current (I_L) through it using Ohm's law as $I_L = \frac{V_L}{R_L}$. Record the values in the corresponding data table.

Data Tables

Signature of Lab Faculty: Jishnu Mahmud **Date:** 23/03/24

** *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)	Notation	Expected Resistance	Observed Resistance (kΩ)
R_1	10 kΩ	9.92	R_5	3.3 kΩ	3.29
R_2	2.2 kΩ	2.173	R_6	1 kΩ	0.98
R_3	2.2 kΩ	2.152	R_L	4.7 kΩ	4.6
R_4	4.7 kΩ	4.61			

Table 2: Data from Circuit 1

In the following table, V_L is the voltage drop across the load resistor R_L and I_L is the current through the load with polarity and direction respectively as shown in **Circuit 1**. Solve the circuit and calculate theoretical V_L and I_L. Also, calculate the percentage of error between experimental and theoretical values of V_L.

Observation	V_{S_1} (V) (from dc supply)	V_{S_1} (V) (using multimeter)	V_{S_2} (V) (from dc supply)	V_{S_2} (V) (using multimeter)	V_L (V)	$I_L = \frac{V_L}{R_L}$ (mA)
Experimental	10	10·05	6	6·03	2V	0·42
Theoretical					1·993V	0·424mA

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

Here, Percentage of Error in V_L calculation = 0·35 %

Table 3: Data from Circuit 2

In the following table, V_{OC} is the open circuit voltage across the open terminals with $I_L = 0$. This is the Thevenin voltage V_{Th}. Calculate the percentage of error between experimental and theoretical values of V_{OC}.

Observation	V_{S_1} (V) (from dc supply)	V_{S_1} (V) (using multimeter)	V_{S_2} (V) (from dc supply)	V_{S_2} (V) (using multimeter)	$V_{OC} = V_{Th}$ (V)
Experimental	10	10·05	6	6·03	3·431 V
Theoretical					3·42 V

Here, % error in $V_{OC} = V_{Th}$ calculation = 0·32 %

CamScanner

Table 4: Data from Circuit 3

In the following table, I_{SC} is the current through the shorted terminals with $V_L = 0$. Theoretically calculate the short circuit current and calculate the percentage of error between experimental and theoretical values of I_{SC}.

Observation	V_{S_1} (V) (from dc supply)	V_{S_1} (V) (using multimeter)	V_{S_2} (V) (from dc supply)	V_{S_2} (V) (using multimeter)	V_{R_1} (V)	$I_{SC} = \frac{V_{R_1}}{R_1}$ (mA)
Experimental	10	10·05	6	6·03	2·27	1·045 mA
Theoretical						1·02 mA

Here, % error in I_{SC} calculation = 2·45 %

Table 5: R_{Th} calculation

Comparison of the two methods to determine R_{Th}.

Here, $\Delta R_{Th} = (R_{Th}\ using\ V_{Th}/I_{SC}\ method) - (R_{Th}\ using\ the\ Universal\ method)$

Observation	V_{Th} (V) (from data Table 3)	I_{SC} (mA) (from data Table 4)	$R_{Th} = \frac{V_{Th}}{I_{SC}}$ (kΩ)	R_{Th} (kΩ) (using multimeter from Circuit 4)	ΔR_{Th} (kΩ)
Experimental	3·431	1·045	3·283	3·252	0·031
Theoretical	3·43	1·02	3·36	3·39	0·03

Table 6: Data from Circuit 5

In the following table, V_L is the voltage drop across the load resistor R_L and I_L is the current through the load with polarity and direction respectively as shown in **Circuit 1** and **Circuit 5**. Measure the value of V_L from **Circuit 5**. Then calculate I_L using the measured V_L. Finally, compare the values with those in Table 1. Here,

$$\Delta V_L = (V_L\ from\ Table\ 2) - (V_L\ measured\ for\ Circuit\ 5\ \text{in Table 6}) \text{ and}$$

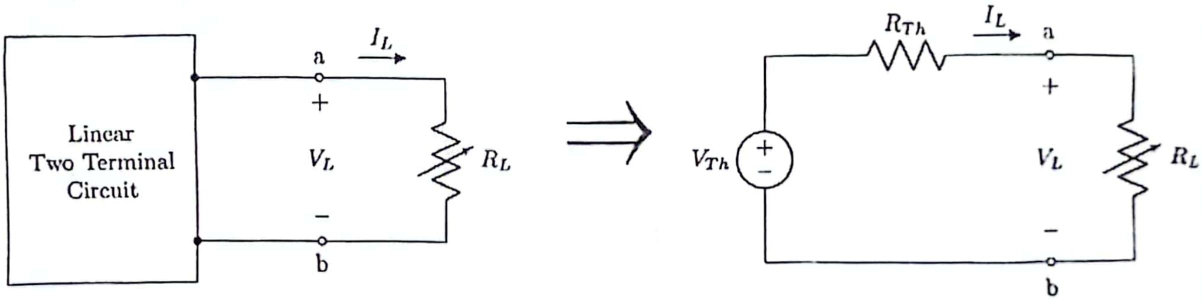
$$\Delta I_L = (I_L\ from\ Table\ 2) - (I_L\ calculated\ for\ Circuit\ 5\ \text{in Table 6}).$$

Observation	V_L (V) (from data Table 2)	I_L (mA) (from data Table 2)	V_L (V) (from Circuit 5 using multimeter)	$I_L = \frac{V_L}{R_L}$ (V) (for Circuit 5)	ΔV_L (V)	ΔI_L (mA)
Experimental	2	0.42	2.003	0.434	0.003	0.014
Theoretical	1.993	0.424	2.002	0.426	0.009	0.02

Part 2: Maximum Power Transfer Theorem

Theory

The Maximum Power Transfer Theorem is a fundamental concept in electrical engineering that relates to the transfer of maximum power from a source to a load. The Maximum Power Transfer theorem states that *A resistive load will receive maximum power when its total resistive value is exactly equal to Thevenin's resistance of the network as "seen" by the load.*



We know that any circuit A terminated with a load R_L can be reduced to its Thevenin equivalent. Now according to this theorem, the load R_L will receive maximum power when $R_L = R_{Th}$. We can calculate the Maximum Power theoretically using the formula,

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

The theorem focuses on the transfer of power between a source and a load. In electrical circuits, power is transferred from a source (such as a generator) to a load (such as a resistor) through a transmission medium (such as wires or conductors).

It's worth noting that the Maximum Power Transfer Theorem is a theoretical concept and is not always practical or desirable in real-world scenarios. In many practical applications, impedance matching is employed to achieve efficient power transfer, but it may not always

Table 7: Data from Circuit 6

In the following table, P_{In} is the power supplied by the dc source of whose value is set equal to V_{Th}, and P_{Load} is the power consumed by the load. η is the power efficiency. Theoretically, η is 50% at the maximum power transfer condition.

R_L (Expected)	R_L (kΩ) (Measured)	V_{Th} (V) (using multimeter)	V_L (V)	$I_L = \frac{V_L}{R_L}$ (mA)	$P_{In} = V_{Th} I_L$ (mW)	$P_{Load} = V_L I_L$ (mW)	Efficiency $\eta = \frac{P_{Load}}{P_{In}} \times 100$ (%)
0.22 kΩ	0·218	3·43	0·213	0·977	3·351	0·298	6·20
1 kΩ	0·98		0·78	0·796	2·730	0·620	7·61
1.5 kΩ	1·47		1·06	0·721	2·47	0·764	30·43
2.2 kΩ	2·152		1·36	0·632	2·16	0·854	34·76
3.3 kΩ	3·306		1·72	0·526	1·78	0·899	50·22
4.7 kΩ	4·6		2·004	0·435	1·492	0·891	58·37
5.6 kΩ	5·6		2·162	0·386	1·324	0·834	63·00
10 kΩ	9·92		2·58	0·26	0·89	0·67	75·3
18 kΩ	17·74		2·897	0·163	0·56	0·472	84·3
33 kΩ	32·5		3·12	0·096	0·33	0·299	90·6

Maximum Power found from the Table 7, P_{max} = 0·09 mW

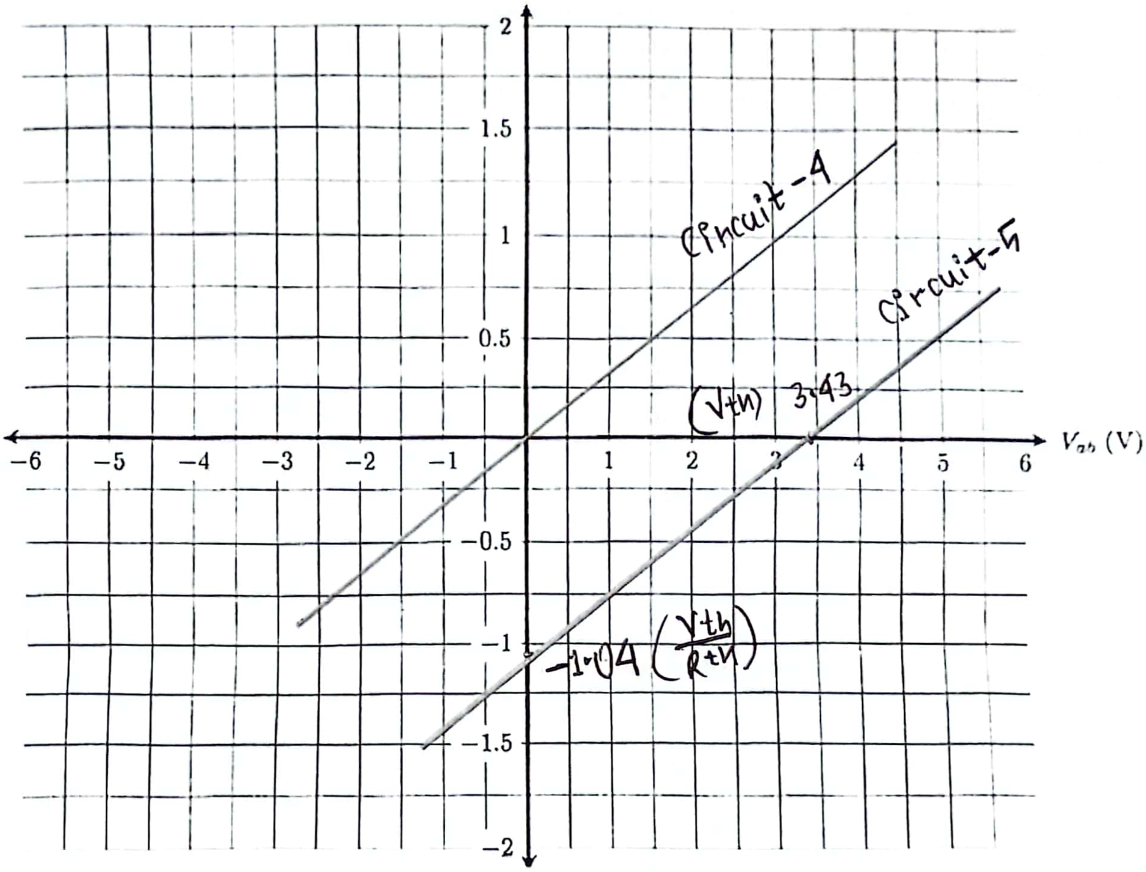
Theoretical Maximum Power, $P_{max} = \frac{V_{Th}^2}{4R_{Th}}$ = 0·09 mW

Here, percentage error in Maximum Powers calculation = 0 %

Questions

1. Circuit equivalency:

(a) Draw the $I - V$ characteristic of the **Circuit 5** to the left of terminals $a - b$ in the template provided below.



The straight line intersects x-axis at 3.43 V

The straight line intersects y-axis at -1.04 mA

Slope of the straight line, m = 0.30 $k\Omega^{-1}$

Resistance from the plot, $\frac{1}{m}$ = 3.283 $k\Omega$

(b) Comparing the values to those measured for **Circuit 1** in Tables 3 (V_{OC}), 4 (I_{SC}), and 5 (R_{Th}), do they closely match?

☑ Yes ☐ No

2. Now in the same plot provided above, plot the $I - V$ curve of **Circuit 4**.

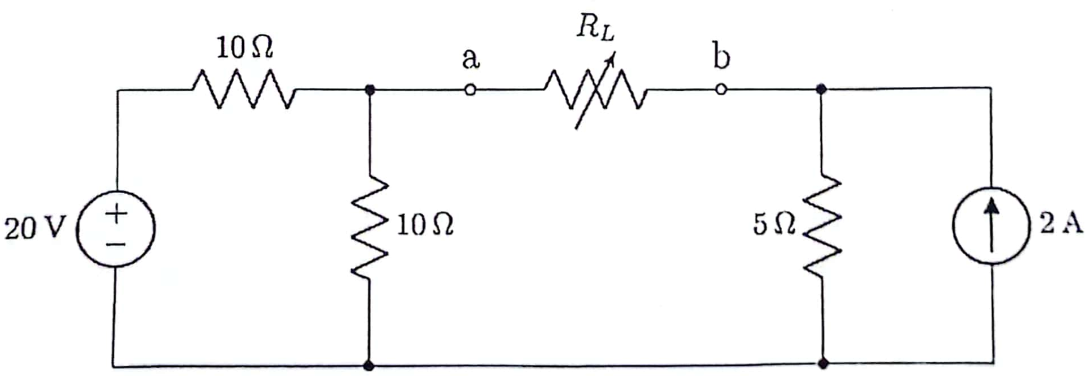
Slope of the straight line, m = $\boxed{0.302 \ k\Omega^{-1}}$

Resistance from the plot, $\frac{1}{m}$ = $\boxed{3.31 \ k\Omega}$

Explain why there is a shift in the $I - V$ curve of Circuit 4.

The shift happened because while plotting for circuit-4, there was only one voltage source, which is load voltage. But in the case of circuit-5 there was one extra V_{th}.

3. Determine the open circuit voltage (V_{OC}) and the short circuit current (I_{SC}) to the terminals $a - b$ for the circuit shown below.



Open circuit voltage, V_{OC} = $\boxed{0 \ \text{V}}$

Short circuit current, I_{SC} = $\boxed{0 \ \text{mA}}$

Have you been able to calculate the Thevenin resistance (R_{Th}) using $R_{Th} = \frac{V_{oc} = V_{Th}}{I_{sc}}$?

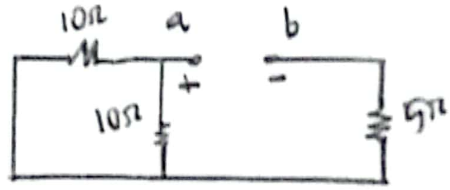
☐ Yes ☑ No

If not, suggest an alternative approach and determine R_{Th}.

We can determine R_{Th} by

turning off all the independent sources; shorting the terminal where the voltage sources were and opening the terminal where current sources existed.

Calculation:



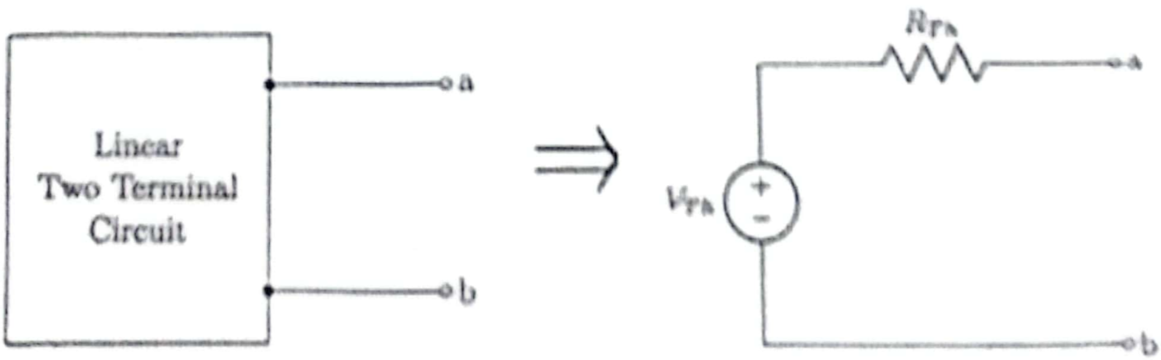
Now $R_{ab} = R_{eq}$

$= (10 \| 10) + 5$

$= 5 + 5$

$\therefore R_{th} = 10\Omega$ (Ans)

4. If the following voltage source is in series with a resistor is the Thevenin equivalent of the linear two-terminal circuit, for each of the circuit elements listed in column 1 of the following table, write the values of V_{Th} and R_{Th}. Write '*Unknown*' if unable to specify.



The linear two-terminal circuit is composed of only a/an	V_{Th} (V)	R_{Th} (Ω)
Short circuit	0	0
Open circuit	unknown	∞
$-2\ V$ ideal voltage source	−2V	unknown
$3\ A$ ideal current source	unknown	unknown
5 kΩ resistor	unknown	5kΩ

5. Efficiency and Maximum Power:

(a) From the η and P_{Load} vs. R_L plot, what is the efficiency at the maximum power position?

η = 60·22 % at the maximum power point position.

(b) For a load resistance R_L,

we can **increase** the power efficiency of the load by –

☑ Increasing R_L than R_{Th} ☐ Decreasing R_L than R_{Th} ☐ By equating R_{Th} and R_L

(c) We can **maximize** the power transfer of the load by –

☐ Increasing R_L than R_{Th} ☐ Decreasing R_L than R_{Th} ☑ By equating R_{Th} and R_L

(d) "We cannot maximize both the power of a load and the power efficiency of the circuit" – justify the statement.

Theoretically efficiency, η is 50% at max power transfer condition. But if we increase the efficiency, it won't maximize load power according to the theory.

6. Specify by putting × *or* ✔, what should be the first priority: maximizing the power or increasing the efficiency for the following applications –

Application	Should Maximize the power transferred to the load	Should try to operate the load with the highest efficiency possible
An antenna sending signal to the Mars	✔	×
A motor running to pull water to a tank placed in a higher position	×	✔
A mic used to amplify voice	✔	×

Report

1. Fill up the theoretical parts of all the data tables.
2. Answers to the questions.
3. Attach two data plots, one should include V_L, I_L, and P_{Load} vs. R_L plotted together in the same pane and the other should include η and P_{Load} vs. R_L plotted together in the same pane. There is a guideline of plotting data using google sheet in the next page.
4. Discussion *[your overall experience, accuracy of the measured data, difficulties experienced, and your thoughts on those]*. Add pages if necessary.

The experiment helped us to gain visualization of the ~~th~~ Thervnin's theoram and maximum power transfer concept.
We ~~prove~~ got ~~prove th~~ proof of that a linearly two terminal circuit can be reduced to a circuit with only a voltage ~~on~~ source and resistor, using thervnins theoram. We also understood the relation between load voltage resistance and power effciency.