FACULATY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Basic Electrical Engineering Lab (ENEE 2101)

Report of Experiment 4

"Network Theorems"

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Abstract:

In this experiment, we will explore techniques for analyzing circuits to determine the voltage between two points and the current flowing through them. The methods used are:

Proportionality, Superposition, Thevenin, Delta-to-why transformation, Reciprocity.

Theory:

The study of electrical circuits and systems through mathematical techniques and theorems is referred to as network theory. This approach helps determine the voltage and current values in a circuit. In this experiment, we will explore five methods for analyzing circuits.

1) **The Proportionality Theorem:** is a principle that indicates that the voltage within a circuit is directly proportional to the applied voltage source. This theorem is mainly used for analyzing linear circuits.
2) **The Superposition Theorem**: it indicates that in a linear circuit containing multiple independent sources, the total voltage and current at any point can be calculated by combining the effects of each independent source acting independently, with all other independent sources turned off.
3) **The Thevenin Theorem**: it simplifies complex linear circuits into simpler equivalent circuits. It indicates that any linear circuit containing voltage sources, current sources, and resistors can be represented by a single voltage source (Thevenin voltage) in series with a single resistor (Thevenin resistance) connected to the load.
4) **The Δ-Y (Delta-Wye) Transformation:** is a method used to simplify complex resistor networks. This technique enables the conversion of a delta (Δ) arrangement of resistors, arranged in a triangular formation, into an equivalent wye (Y) configuration.

5) **The Reciprocity Theorem:** indicates that the current in one branch caused by a voltage source in a different branch is the same as the current that would flow if the voltage source were moved to the first branch.

Procedure:

Part A: The Proportionality Theorem

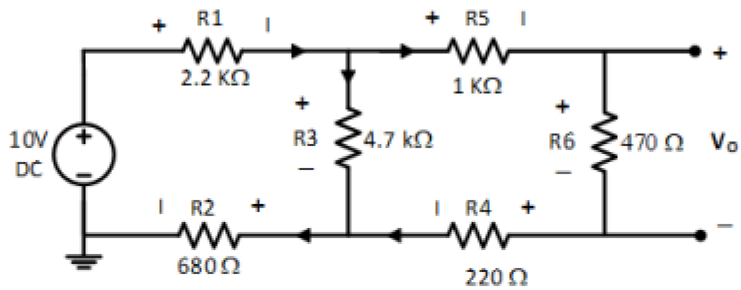

Figure 1: 4.1

We connect the circuit in Figure 4.1, then set Vin to 5V, measure Vo, and record the results in Table 4.1. We repeat the same steps with Vin set to 10V.

Part B: The superposition Theorem

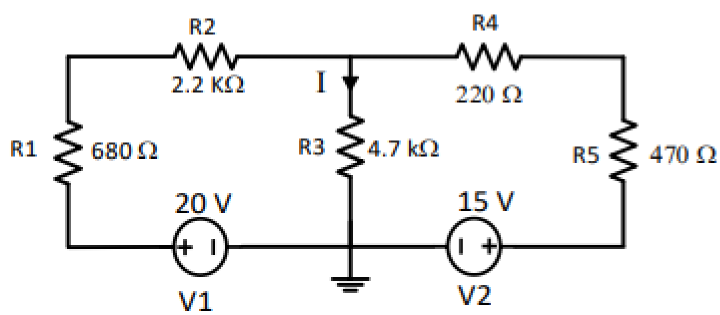

Figure 2: 4.2

We connected the circuit shown in Figure 4.2, and set the power supply voltages as follows: V1 = 20 V and V2 = 15 V. We then measured the voltage and current across the 2.2 kΩ resistor and recorded the results in Table 4.2.

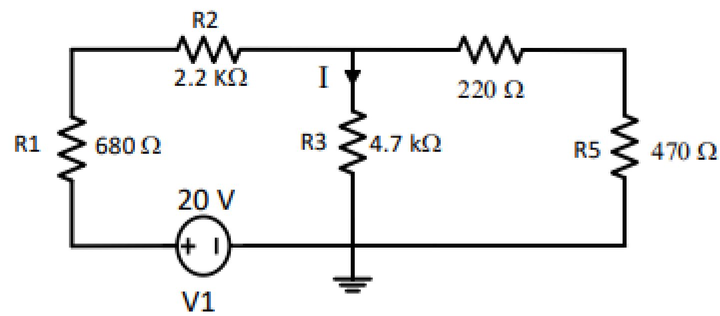

Figure 3 : 4.3

We then connected the circuit shown in Figure 4.3 by removing V2 = 15 V, and measured the voltage and current across the 4.7 kΩ resistor. The results were recorded in Table 4.2.

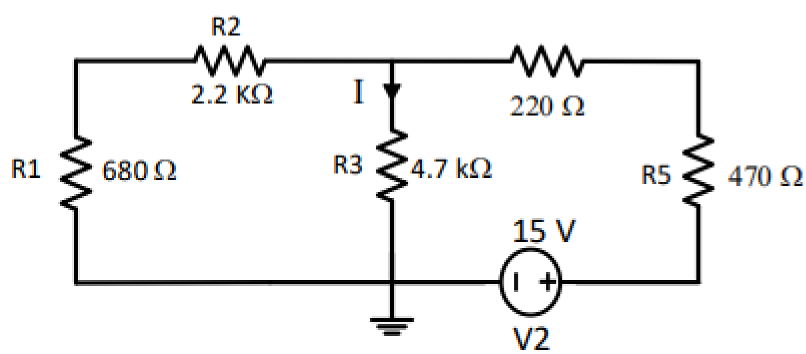

Figure 4: 4.4

We then connected the circuit shown in Figure 4.4 by removing V1 = 20 V, and measured the voltage and current through the 4.7 kΩ resistor. The results were recorded in Table 4.2.

Part C: Thevenin Theorem

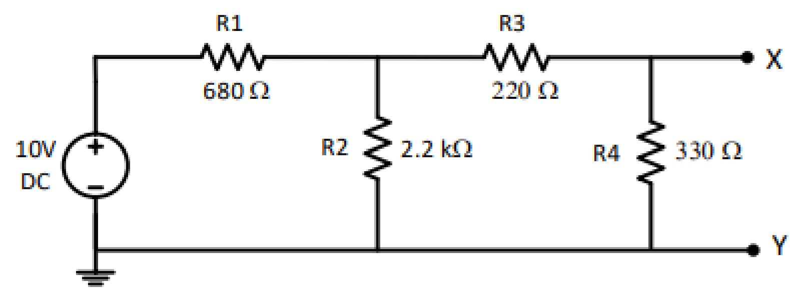

Figure 5: 4.5

We connected the circuit shown in Figure 4.5 and set the power supply voltage to 10 V. Then we measured the voltage and current through the 680 Ω resistor and recorded the results in Table 4.3.

We then removed the 330 Ω resistor from the circuit and measured the voltage in the open circuit. We also measured the current in the short circuit and recorded the results in Table 4.4

We have three methods to calculate Rth (Thevenin resistance).

- **First method:** we can calculate it using the equation $Rth = \frac{Voc}{Isc}$, where Voc is the open-circuit voltage and Isc is the short-circuit current. We then recorded the value of Rth in Table 4.4.

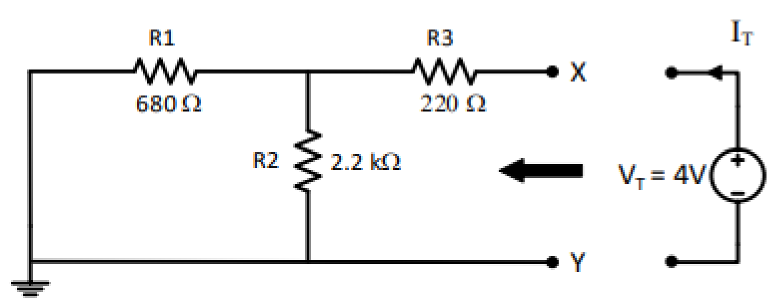

Figure 6: 4.6

- **second method**: we can calculate it using a test voltage source method. First, replace the original 10V voltage source with a short circuit shown in Figure 4.6. Then, connect a 4V test voltage source across the terminals of the network. Measure the resulting test current (It) and calculate the Thevenin resistance using the equation $Rth = \frac{Vt}{It}$ then record the results in Table 4.5.

- **Third Method:** we can calculate it by directly measuring it with an ohmmeter. First, remove any independent sources in the circuit by replacing voltage sources with short circuits and current sources with open circuits. Then, connect an ohmmeter in place of the test voltage source as shown in Figure 4.6. The ohmmeter will directly measure the Rth, then Record the results in Table 4.6.

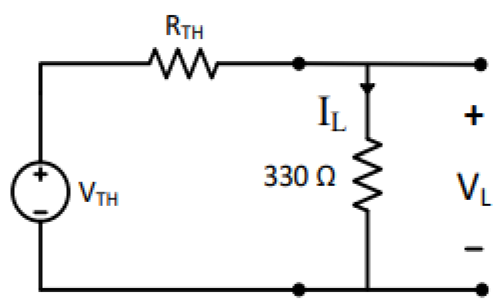

Figure 7: 4.7

Based on our pre-lab calculations, connect the Thevenin equivalent circuit for Figure 4.5 as shown in Figure 4.7. Then, measure the voltage across and the current through the 330Ω resistor. Record the measured voltage and current values in Table 4.7.

Part D: The Reciprocity Theorem

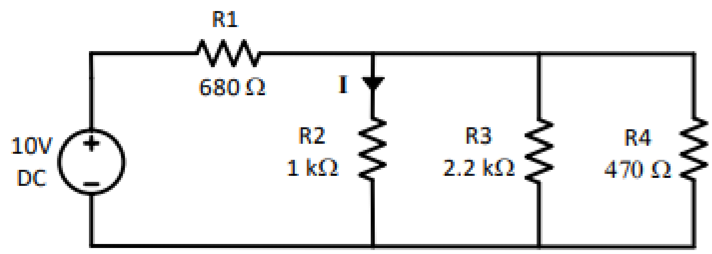

Figure 8: 4.8

Connect the circuit as shown in Figure 4.8. Then, measure the value of the current I flowing through the circuit. Record the measured current in Table 4.8.

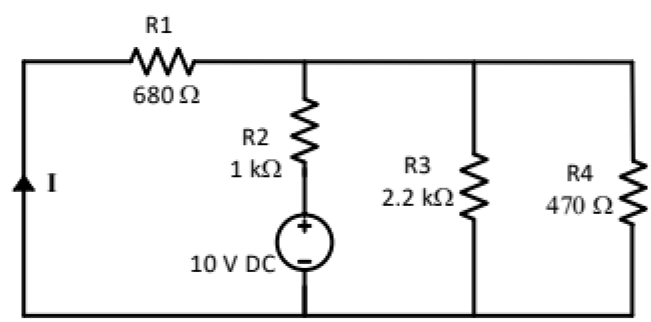

Figure 9: 4.9

Connect the circuit as shown in Figure 4.9. Then, measure the value of the current I flowing through the circuit. Record the measured current in Table 4.8.

Data, calculations, and analysis of results:

<u>Part A: proportionality Theorem:</u>

Table 1 : table 4.1

Vi	Vo(V)	(K = Vo/Vin)
5V	0.415	K=0.415/5 => k = 0.083
10V	0.836	K=0.836/10 =>k=0.0836

First, we measure the output voltage (Vo) by setting the input voltage (Vi) to 5V and 10V, respectively. Then, we calculate the ratio $K = \frac{Vo}{Vin}$, which should remain the same for both values of Vi.

As observed, the values of K in both cases are equal. Therefore, we conclude that the measurements taken in the laboratory are acceptable.

Part B: Superposition Theorem:

In this part, we must calculate the voltage and current across the 4.7kΩ resistor in three cases.

The first case involves the circuit shown in Figure 4.2, where V1 = 20V and V2 = 15V.

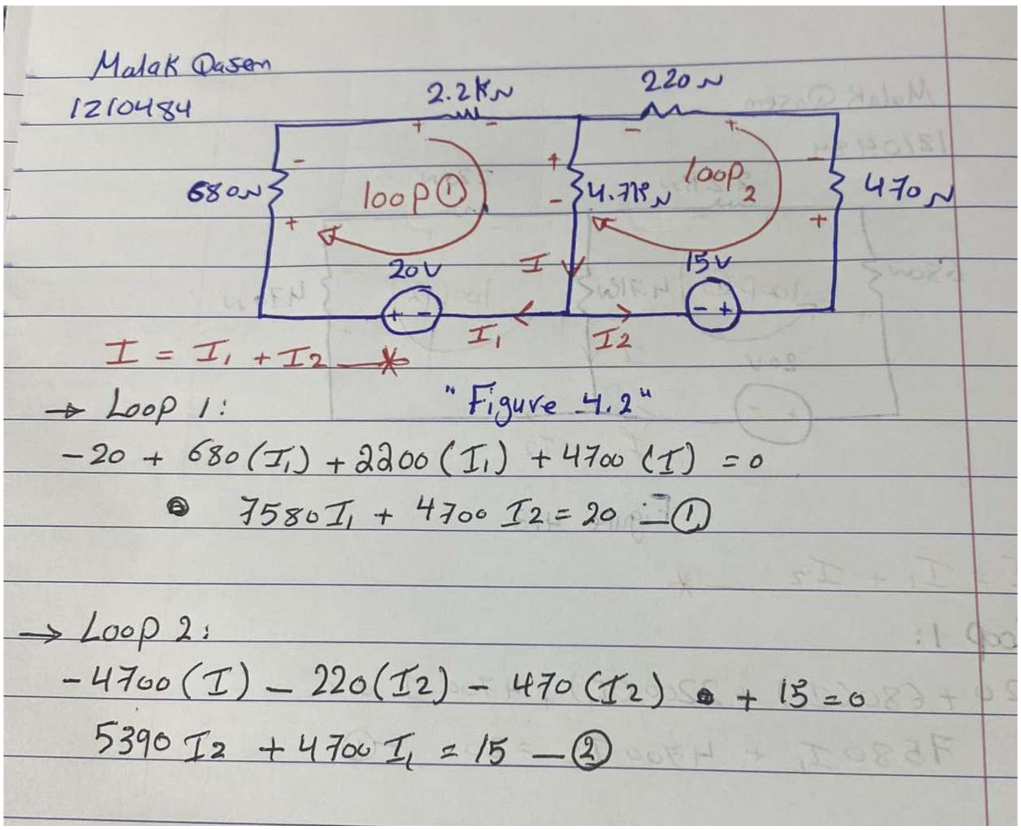

Figure 10: calculations of figure 4.2

After solving the three equations, we get the values I1=1.99mA and I2=1.05mA, and by adding them together, we get the total current I=3.04mA.

Next, we want to calculate the voltage across the 4.7kΩ resistor using the formula V = IR.

Thus, V=3.04 mA×4.7 kΩ=14.28V

In the second case, we analyze the circuit shown in Figure 4.3, where V2=15V is removed, and we calculate the values only with V1=20V.

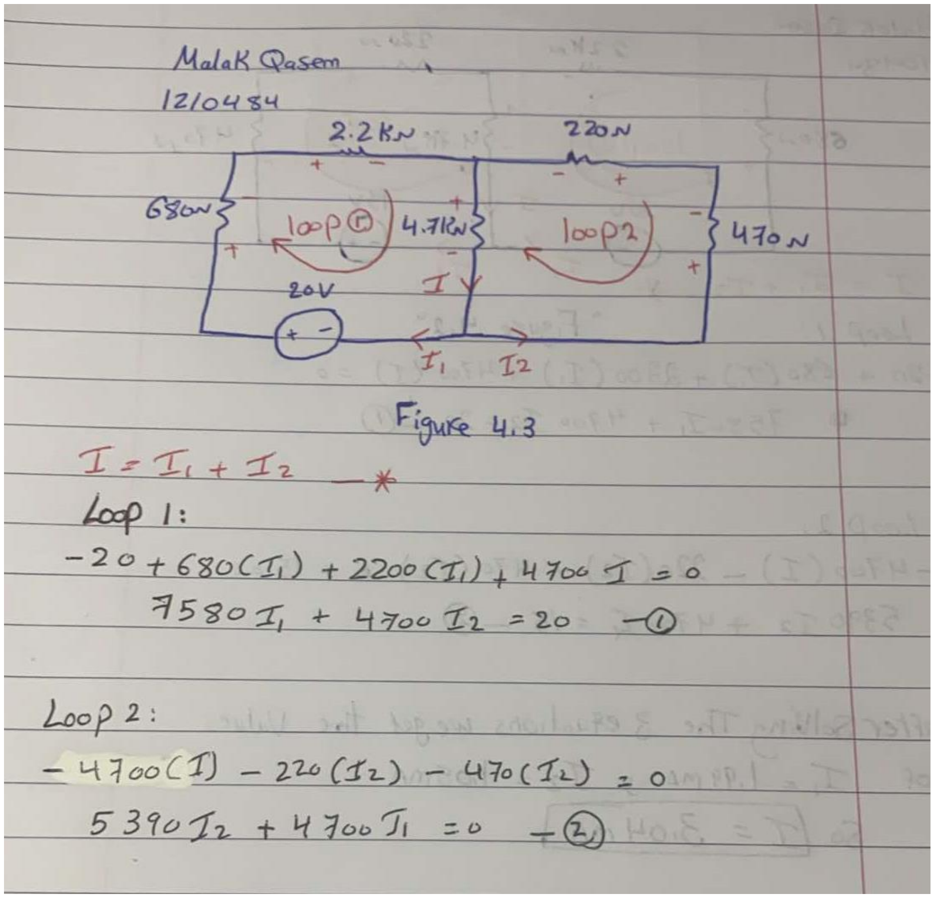

Figure 11: calculations of figure 4.3

After solving the three equations, we get the values I1=5.74mA and I2=-5 mA, and by adding them together, we get the total current I=0.74mA.

Next, we want to calculate the voltage across the 4.7kΩ resistor using the formula V = IR.

Thus, V=0.74 mA×4.7 kΩ=3.478V

In the third case, we analyze the circuit shown in Figure 4.4, where V1=20V is removed, and we calculate the values only with V2=15V.

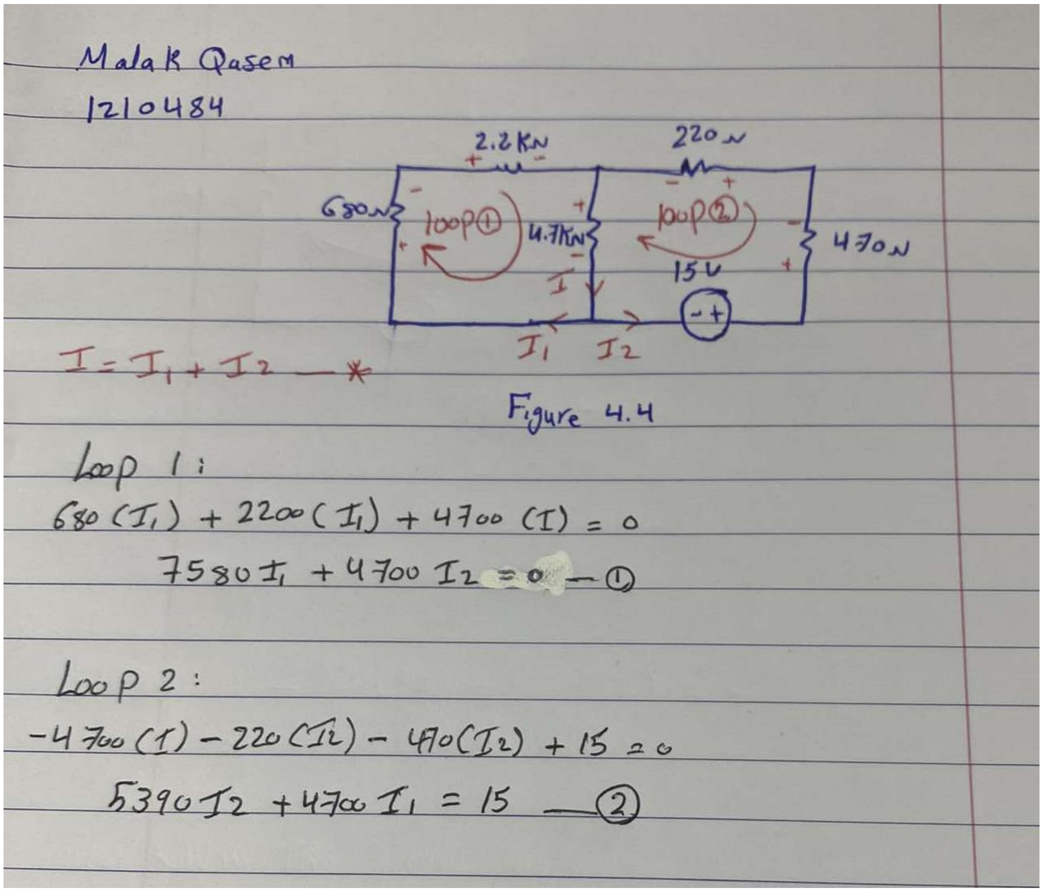

Figure 12: calculations of figure 4.4

After solving the three equations, we get the values I1=-3.756mA and I2=6.058mA, and by adding them together, we get the total current I=2.302mA.

Next, we want to calculate the voltage across the 4.7kΩ resistor using the formula V = IR.

Thus, V=2.302 mA×4.7 kΩ=10.819V

Theoretical values, as calculated earlier:

Table 2: table 4.2.1

	V(4.7KΩ) [V]	I(4.7KΩ) [mA]
Total Response (V1=20V, V2=15V)	14.28	3.04
Response 1 (V1=20V, V2=0V)	3.478	0.74
Response 2 (V1=0V, V2=15V)	10.819	2.302
Response 1 + Response 2	14.297	3.042

Practical values, as measured in the laboratory:

Table 3: table 4.2.2

	V(4.7KΩ) [V]	I(4.7KΩ) [mA]
Total Response (V1=20V, V2=15V)	14.31	3.07
Response 1 (V1=20V, V2=0V)	3.477	0.75
Response 2 (V1=0V, V2=15V)	10.825	2.33
Response 1 + Response 2	14.302	3.08

So, we concluded that the values of the total response are nearly equal to the sum of response 1 and response 2, for both the theoretical and practical values.

Part C: Thevenin Theorem

We must calculate the voltage and current across the circuit shown in Figure 4.5, using three different methods to measure them.

Table 4: table 4.3

V(330Ω) [V]	I(330Ω) [mA]
2.388	7.25

As shown in Table 4.3, we first measured the voltage and current across the 330Ω resistor.

The first method:

We removed the 330Ω resistor from the circuit, then measured the voltage across the open circuit and the current across the short circuit. then, we calculated the Thevenin resistance Rth using the equation { $Rth = \frac{Voc}{Isc}$ }.

Table 5: table 4.4

V(Open circuit) [V]	I(Short circuit) [mA]	Rth (calculated) [Ω]
7.692	10.47	Rth= 7.692/10.47=735Ω

The second method:

We replace the 10V source with a short circuit, then connect a 4V test voltage source. After that, we measure the voltage and current across the circuit, then calculate the value of Rth using the equation{ $Rth = \frac{Vt}{It}$ }.

Table 6: table 4.5

Vtest(Set)	Itest(Measure) [mA]	Rth (calculated) [Ω]
4V	5.56	Rth= 4/5.56=719Ω

The third method:

"We can also calculate the value of Rth by connecting an ohmmeter in place of the test voltage source. The ohmmeter will directly measure the value of Rth

Table 7: table 4.6

Rth [Ω]	**0.724kΩ => 724Ω**

Then, we must measure the value of the voltage and current across the 330Ω resistor.

Table 8: table 4.7

V(330Ω) [V]	I(330Ω) [mA]
2.372	7.21

in the end, we have three values of Rth and we conclude that the values of Rth are nearly equal to each other.

<u>Part D: The Reciprocity Theorem</u>

We connected the circuits in Figures 4.8 and 4.9 to calculate the values of the currents I1 and I2.

Table 9: table 4.8

I1 [mA]	I2 [mA]
2.99	2.98

As shown in Table 4.8, the values of I1 and I2I are almost equal.

Conclusion:

In summary, in this experiment, we learned several methods to simplify circuits: **Proportionality, Superposition, Thevenin, and Reciprocity**. As shown in the section that summarized the data and calculations, we noticed that the values of voltage, current, and resistance almost equal. Therefore, we conclude that the experiment was successful.

References:

-Data sheet.

Experiment 4 - Data Tables:

Part A: The Proportionality Theorem

Table 4.1

Vi	Vo [V]	$(K = V_O / V_{in})$
5 V	0.415	K=0.415/5 ⟹ K=0.083
10 V	0.836	K=0.836/10 ⟹ K=0.0836

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9/10/2024

Part B: The Superposition Theorem

Table 4.2

	V (4.7 kΩ) [V]	I (4.7 kΩ) [mA]
Total Response $(V_1 = 20\ V, V_2 = 15\ V)$	14.31	3.07
Response 1 $(V_1 = 20\ V, V_2 = 0\ V)$	3.477	0.75
Response 2 $(V_1 = 0\ V, V_2 = 15\ V)$	10.825	2.33
Response 1 + Response 2	14.302	3.08

Part C: Thevenin Theorem

Table 4.3

V (330 Ω) [V]	I (330 Ω) [mA]
2.388	7.25

Table 4.4

V (open circuit) [V]	I (Short circuit) [mA]	R_{TH} (Calculate) [Ω]
7.692	10.47	$R_{th} = \frac{V}{I} \Rightarrow R_{th} = 735\ \Omega$

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Figure 13: Data sheet 1

Table 4.5

V_{Test} (SET)	I_{Test} (Measure) [mA]	R_{TH} (Calculate) [Ω]
4 V	5.56	$Rth = \frac{V}{I} \Rightarrow Rth = 719\ \Omega$

Table 4.6

R_{Th} [Ω]	0.724K ⟹ 724 Ω

Table 4.7

V (330 Ω) [V]	I (330 Ω) [mA]
2.372	7.21

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9/10/2024

Part D: The Reciprocity Theorem

Table 4.8

I_1 [mA]	I_2 [mA]
2.99	2.98

Figure 14: Date sheet 2