Lab Report: Electrical Circuits (CSE 209)

Expt. No: 06

Title: Verification of Superposition Theorem.

Submitted by-

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Objective:

1. To verify the superposition theorem theoretically, experimentally, and using PSpice simulation.

Theory:

Superposition theorem works for linear circuits. The superposition theorem states that if a linear circuit contains more than one source, the voltage across or the current through any element may be determined by algebraically adding the contribution of each source acting alone with other sources remaining inactive. A voltage source is made inactive by setting its voltage value to zero (or by replacing it with a short circuit).

$E_1 = 10V$, $E_2 = 5V$, $E_3 = 5V$

$R_1 = 33\Omega$ $R_2 = 47\Omega$ $R_3 = 33\Omega$ $R_4 = 47\Omega$ $R_5 = 47\Omega$ $R_L = 68\Omega$

Circuit Diagrams:

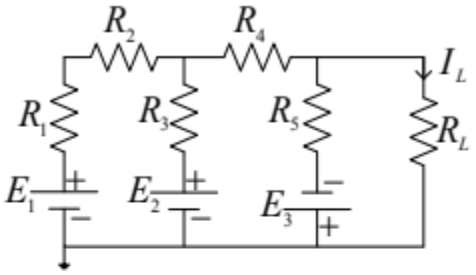


Figure 1. Circuit with all sources active.

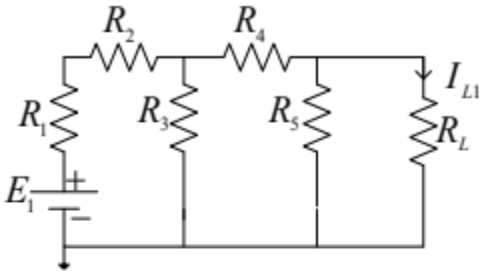


Figure 2. Circuit with E_1 source active.

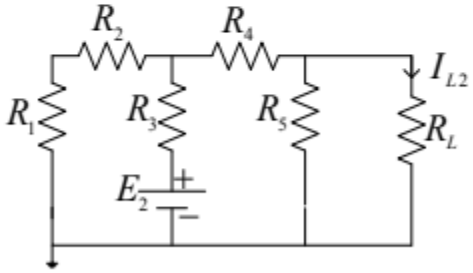


Figure 3. Circuit with E_2 source active.

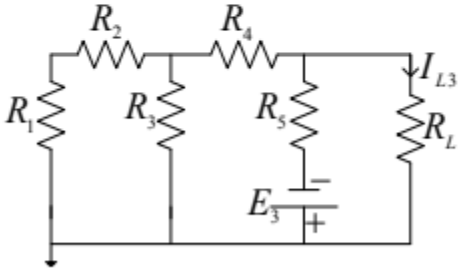
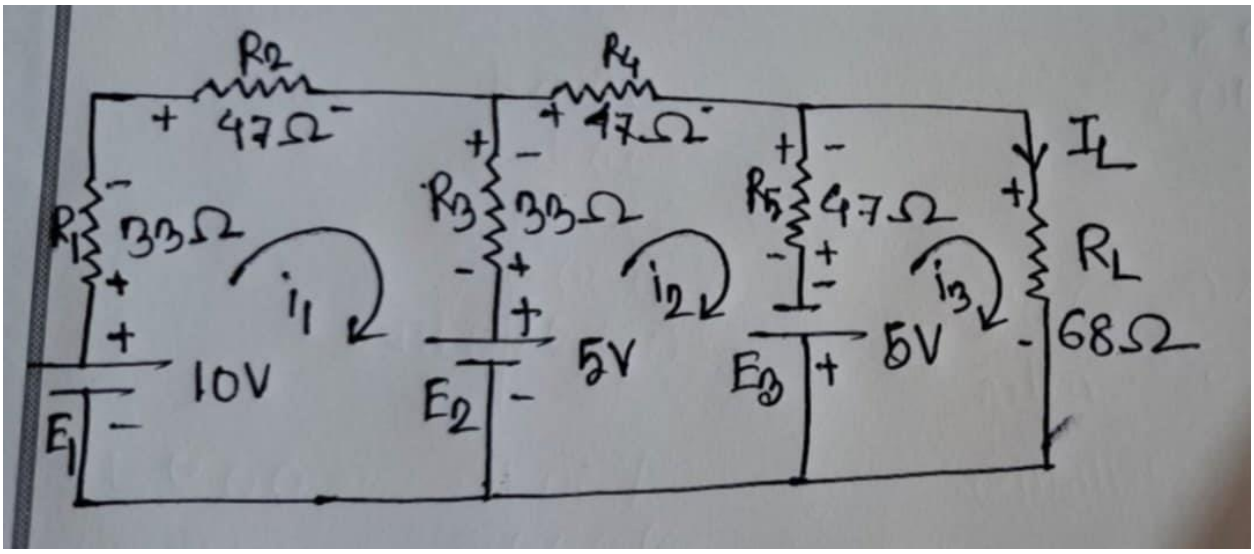


Figure 4. Circuit with E_3 sources active.

Pre-Lab Report Question:

1. **Theoretically calculate the values of I_L, I_{L1}, I_{L2}, I_{L3} of the circuits of figure 1 through 4. The calculated values show that the superposition theorem holds, that is $I_L = I_{L1} + I_{L2} + I_{L3}$**

Solutions:



Applying KVL at mesh 1,2,3

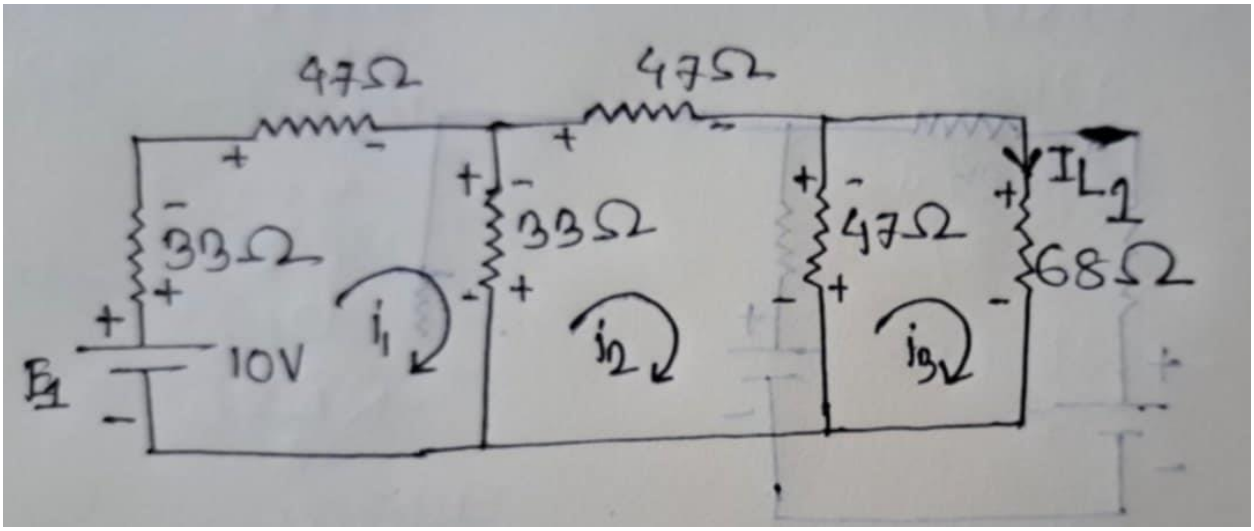
$(33+ 47+ 33)i_1 – 33i_2 = 10-5 = 5$ …….(i)

$-33i_1 + (33+ 47+ 47)i_2 – 47i_3 = 5+5 = 10$…..(ii)

$-47i_2+ (47+68)i_3 = -5$……(iii)

By solving,

$I_L = i_3 = -4.269$ mA



Applying KVL at mesh 1,2,3

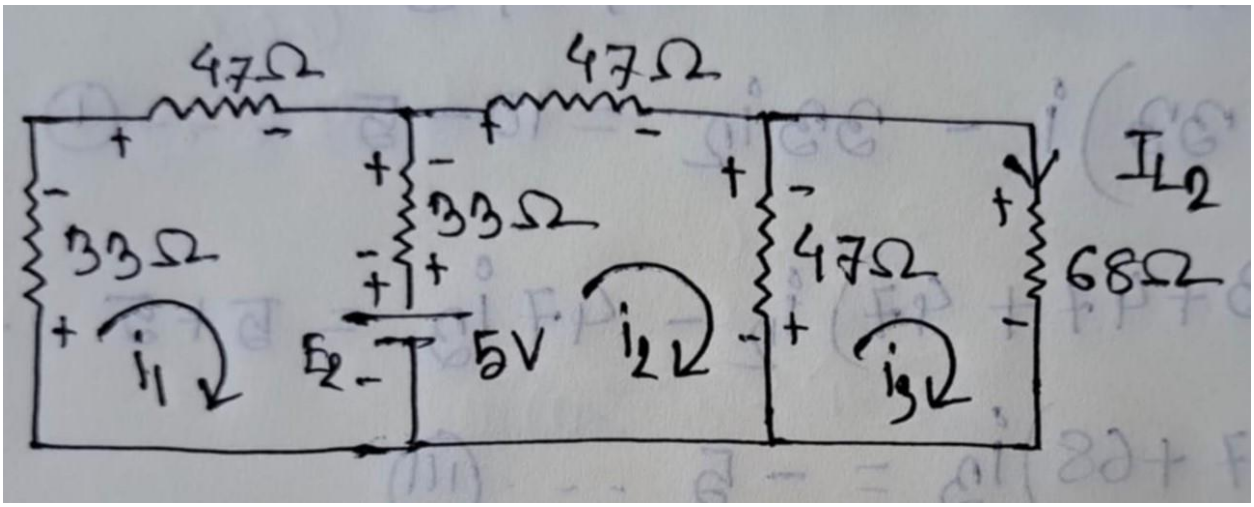
$(33+ 47+ 33)i_1 – 33i_2 = 10$…….(i)

$-33i_1 + (33+ 47+ 47)i_2 – 47i_3 = 0$…..(ii)

$-47i_2 + (47+68)i_3 = 0$……(iii)

By solving,

$I_{L1} = i_3 = 12.16$ mA



Applying KVL at mesh 1,2,3

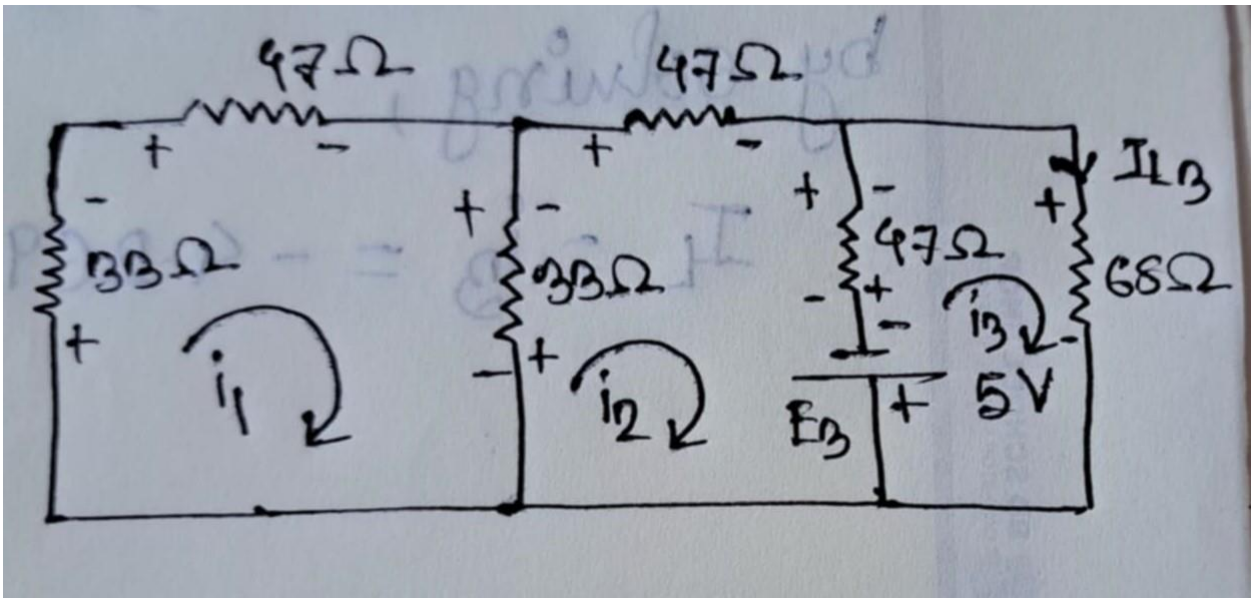
$(33+ 47+ 33)i_1 – 33i_2 = -5$ …….(i)

$-33i_1 + (33+ 47+ 47)i_2 – 47i_3 = 5$…..(ii)

$-47i_2 + (47+68)i_3 = 0$……(iii)

By solving,

$I_{L2} = i_3 = 14.739$ mA



Applying KVL at mesh 1,2,3

$(33+ 47+ 33)\ i_1 – 33i_2 = 0$ ……. (i)

$-33i_1 + (33+ 47+ 47)\ i_2 – 47i_3 = 5$…(ii)

$-47i_2 + (47+68)\ i_3 = -5$……(iii)

By solving,

$I_{L3} = i_3 = -31.168$ mA

Now, **$I_{L1} + I_{L2} + I_{L3}$ = 12.16 + 14.739 + (-31.168) = -4.269 mA = I_L**

Therefore, the Superposition Theorem is verified.

Equipments and Components Needed:

1. DC power supply
2. Trainer board
3. DC ammeter
4. Multimeter
5. Resistors 33Ω (two), 47Ω (three), 68Ω (one)
6. Breadboard
7. Connecting wires

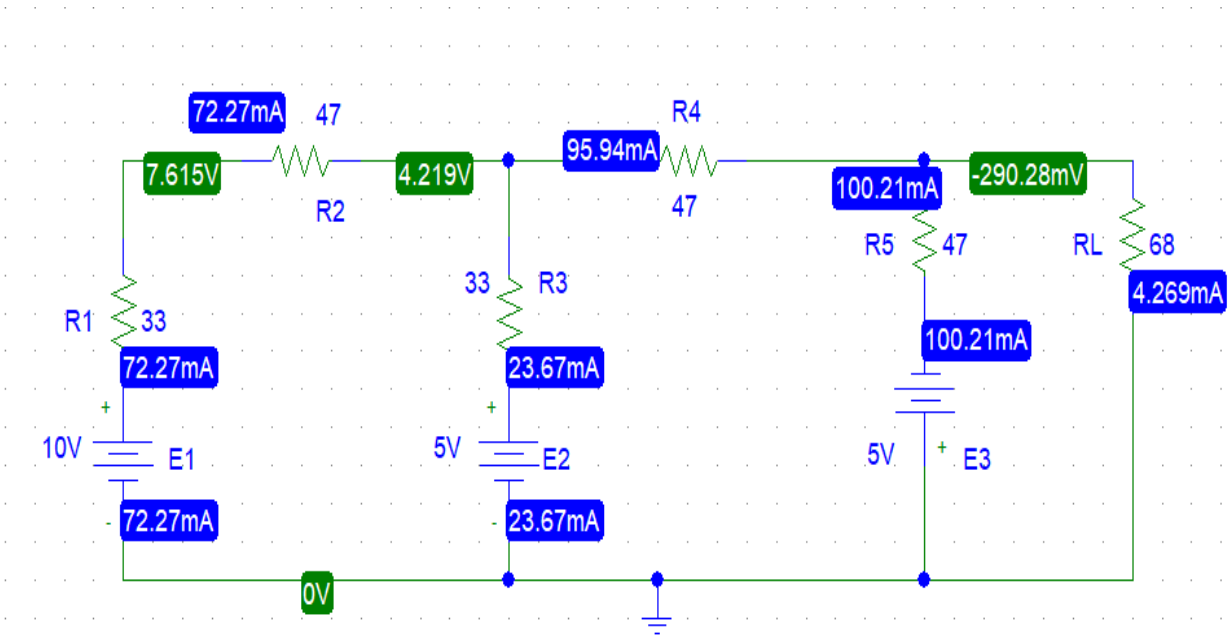


Figure 01: Circuit with all sources active

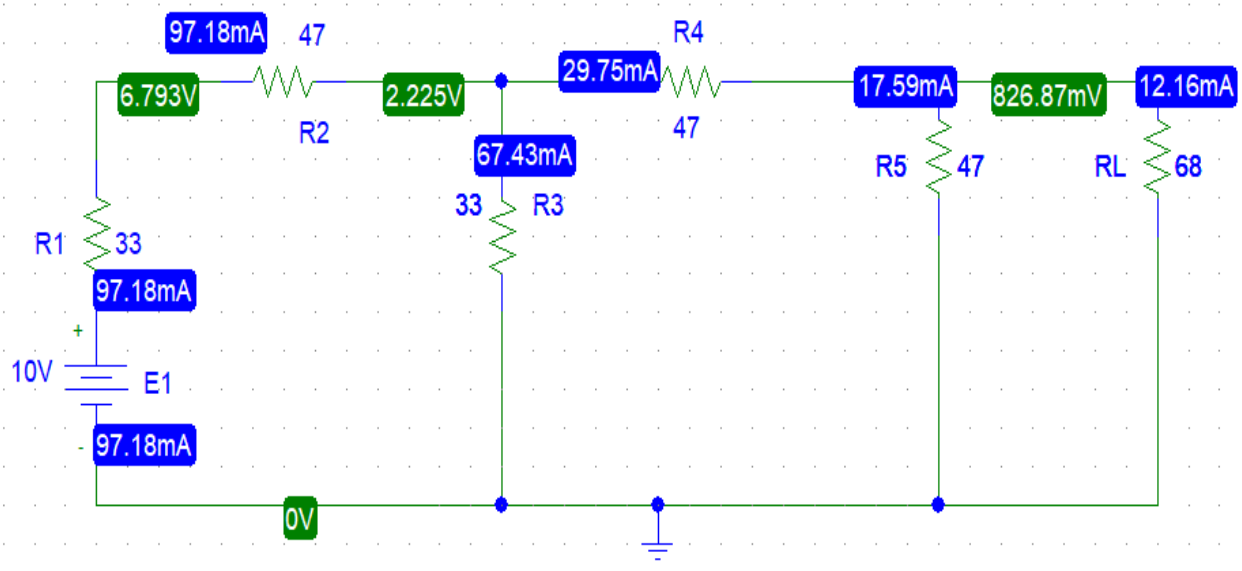


Figure 2: Circuit with E_1 source active.

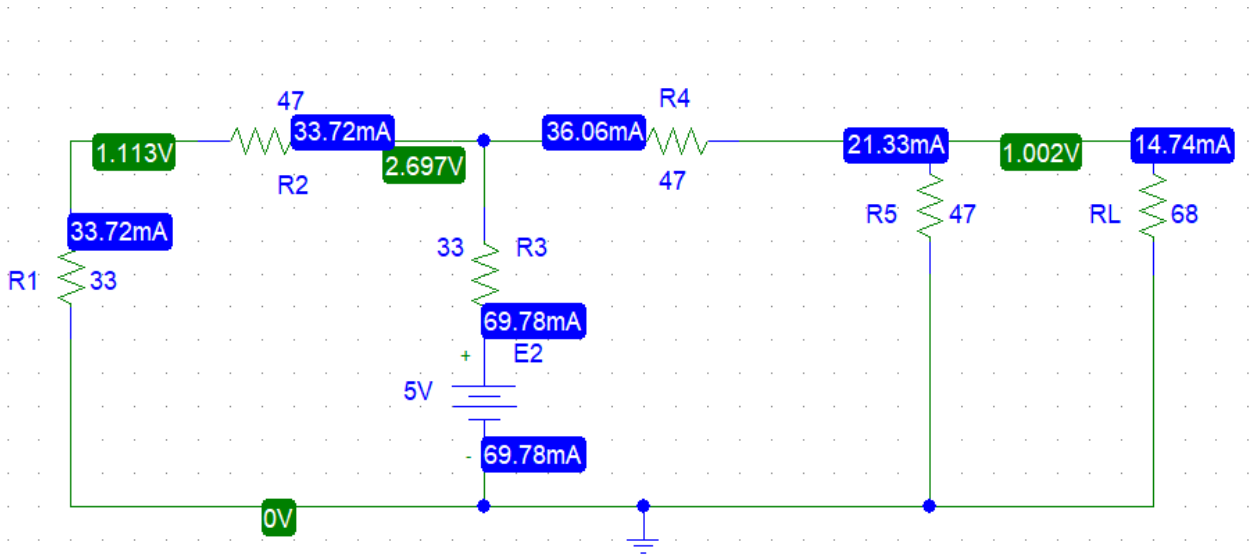


Figure 3: Circuit with E_2 source active

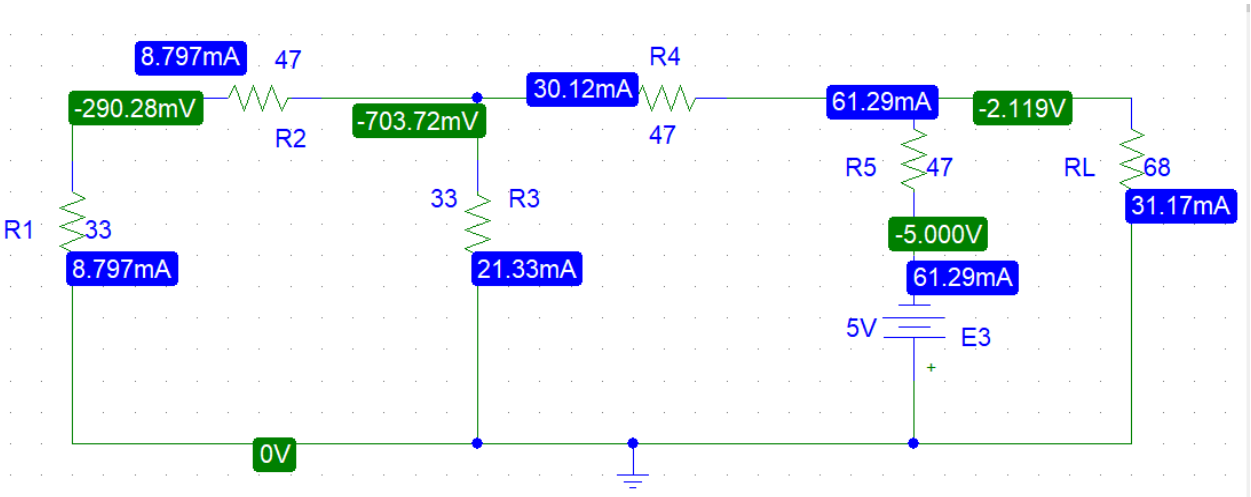


Figure 4: Circuit with E_3 sources active

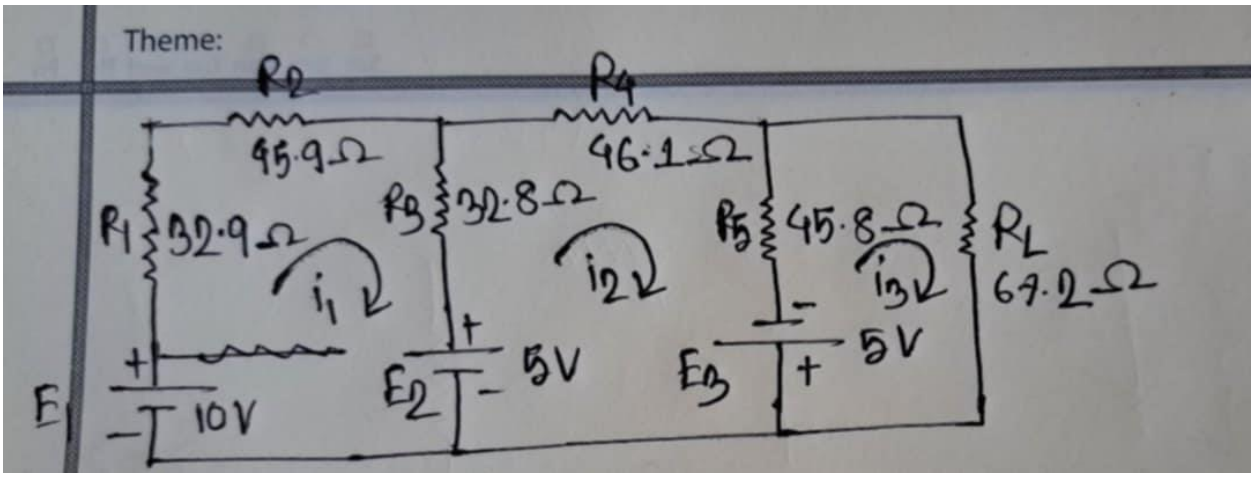
Table 1: Experimental Datasheet

Measured Value of E1 (V)	Measured Value of E2 (V)	Measured Value of E3 (V)	Measured value of IL with all sources active (mA)	Measured value of IL1 with only E1 active (mA)	Measured value of IL2 with only E2 active (mA)	Measured value of IL3 with only E3 active (mA)	Measured value of resistors (Ω)
10	5	-5	-4.04	12.55	14.58	-31.39	R_1=32.9 R_2=45.9 R_3=32.8 R_4=46.1 R_5=45.8 R_L=67.2

Post Lab questions & answers:

1. Calculate the values of I_L, I_{L1}, I_{L2}, and I_{L3} of the circuits of Figures 1 through 4 using the measured values of E_1, E_2, E_3, R_1, R_2, R_3, R_4, R_5, and RL. The calculated values show that the superposition theorem holds. Compare these calculated values of currents with the experimental values and comment on any discrepancy observed.

Solution:



R_1=32.9, R_2=45.9, R_3=32.8, R_4=46.1, R_5=45.8 , R_L=67.2

E_1 = 10 V, E_2 = 5V, E_3 = 5V

Applying KVL at mesh 1, 2,3

$(32.9+ 45.9+ 32.8)\, i_1 – 32.8i_2 = 10-5 = 5$

⇨ $111.6i_1 – 32.8i_2=5$……(i)

$-32.8i_1 + (32.8+ 46.1+ 45.8)\, i_2 – 45.8i_3 = 5+5 = 10$

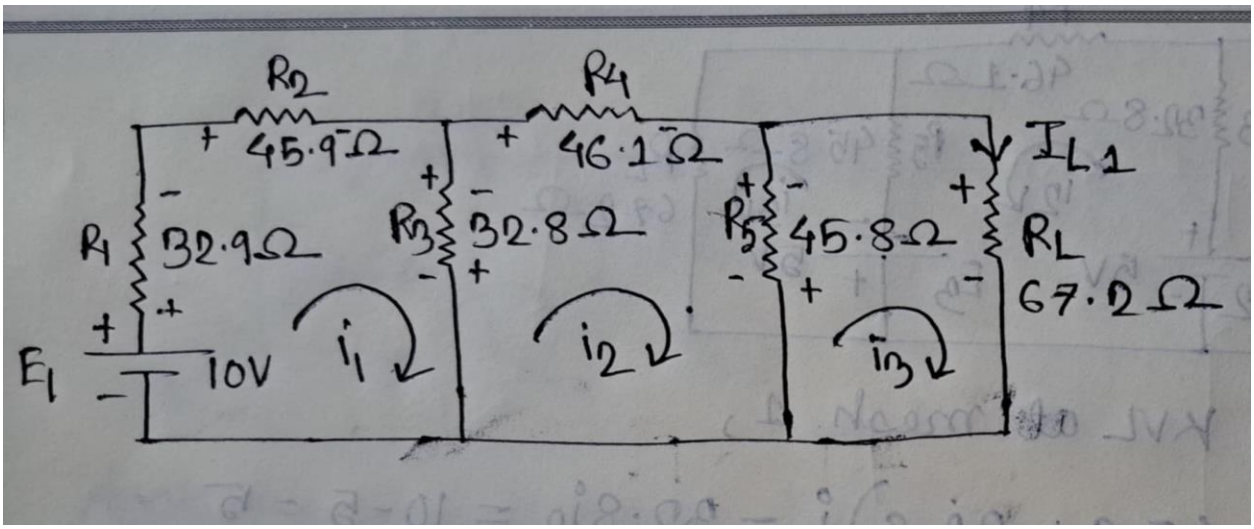
⇨ $-32.8i_1 +124i_2 – 45i_3 = 10$ ……(ii)

$-45.8i_2 + (45.8+ 67.2)i_3 = -5$

⇨ $-45.8i_2 + 113i_3 = - 5$…….(iii)

By solving,

$I_L = i_3 = - 4.58$ mA



Applying KVL at mesh 1,2,3

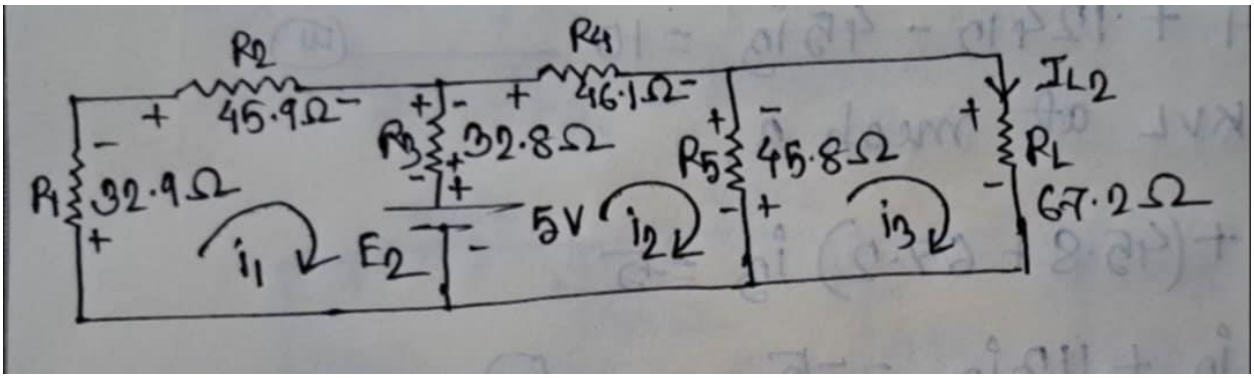
$(32.9+ 45.9+ 32.8)i_1 – 32.8i_2 = 10$…….(i)

$-32.8i_1 + (32.8+ 46.1+ 45.8)i_2 – 45.8i_3 = 0$…..(ii)

$-45.8i_2+ (475.8+67.2)i_3 = 0$……(iii)

By solving,

$IL_1 = i_3 = 12.35$ mA



Applying KVL at mesh 1,2,3

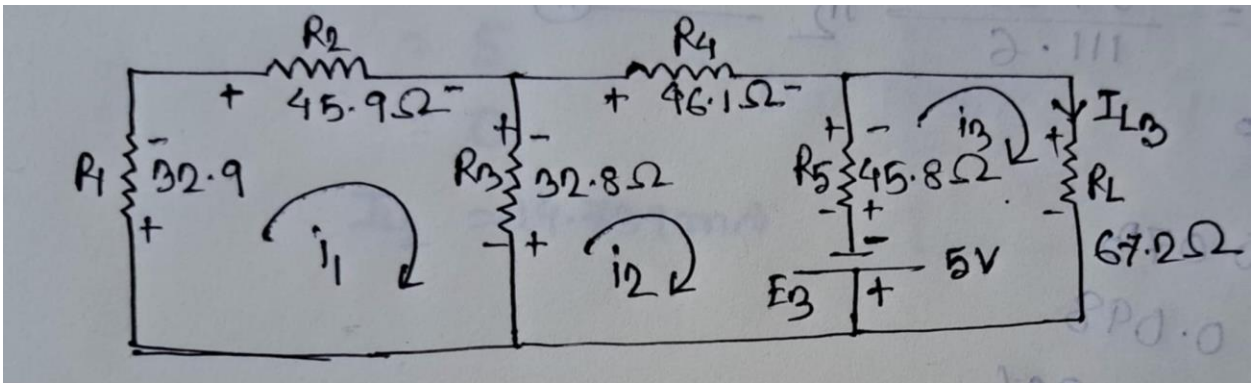
$(32.9+ 45.9+ 32.8)i_1 – 32.8i_2 = -5$…….(i)

$-32.8i_1 + (32.8+ 46.1+ 45.8)i_2 – 45.8i_3 = 5$…..(ii)

$-45.8i_2+ (475.8+67.2)i_3 = 0$……(iii)

By solving,

$IL_2 = i_3 = 14.83$ mA



Applying KVL at mesh 1,2,3

$(32.9+ 45.9+ 32.8)i_1 – 32.8i_2 = 0$…….(i)

$-32.8i_1 + (32.8+ 46.1+ 45.8)i_2 – 45.8i_3 = 5$…..(ii)

$-45.8i_2+ (475.8+67.2)i_3 = - 5$……(iii)

By solving,

$I_{L3} = i_3 = -31.45$ mA

Now, **$I_{L1} + I_{L2} + I_{L3}$ = 12.35+ 14.83 + (-31.76) = -4.58 mA = I_L**

Therefore, it holds the superposition theorem.

Calculated Values of Current (mA)	Experimental Values of Current (mA)
$I_L = - 4.58$	$I_L = -4.04$
$I_{L1} = 12.35$	$I_{L1} = 12.55$
$I_{L2} = 14.83$	$I_{L2} = 14.58$
$I_{L3} = -31.76$	$I_{L3} = -31.39$

There is a discrepancy between calculated and experimental values of currents.

Error Analysis:

Error of I_L = ((-4.58 – (- 4. 04)) / -4.58) * 100 = 0.11 *100 = 11.7 %

Error of I_{L1} = ((12.35 – 12.55) / 12.35) * 100 = -1.6 %

Error of I_{L2} = ((14.83 – 14.58)/14.83) * 100 = 1.68 %

Error of I_{L3} = ((-31.76 – (-31.39) / -31.76) *100 = 1.16 %

2. **Solve the circuits of Figures 1 through 4 using PSpice. Include the PSpice circuits with only currents shown. From the PSpice solution show that the superposition theorem holds. Compare the PSpice solutions with the theoretical solutions and comment on any discrepancy found.**

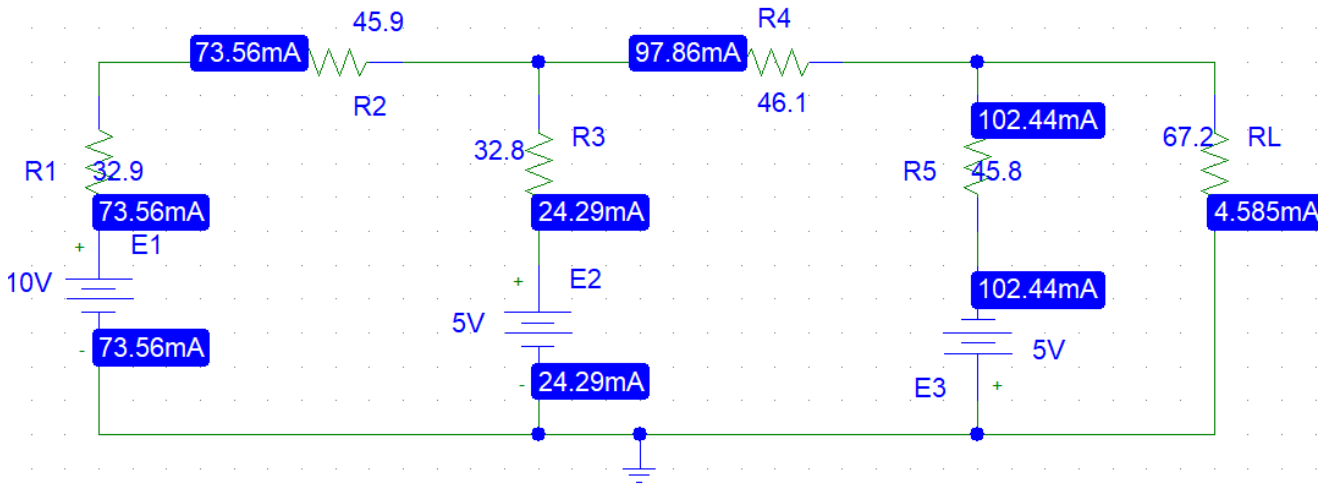


Figure 1: Circuit with all sources active

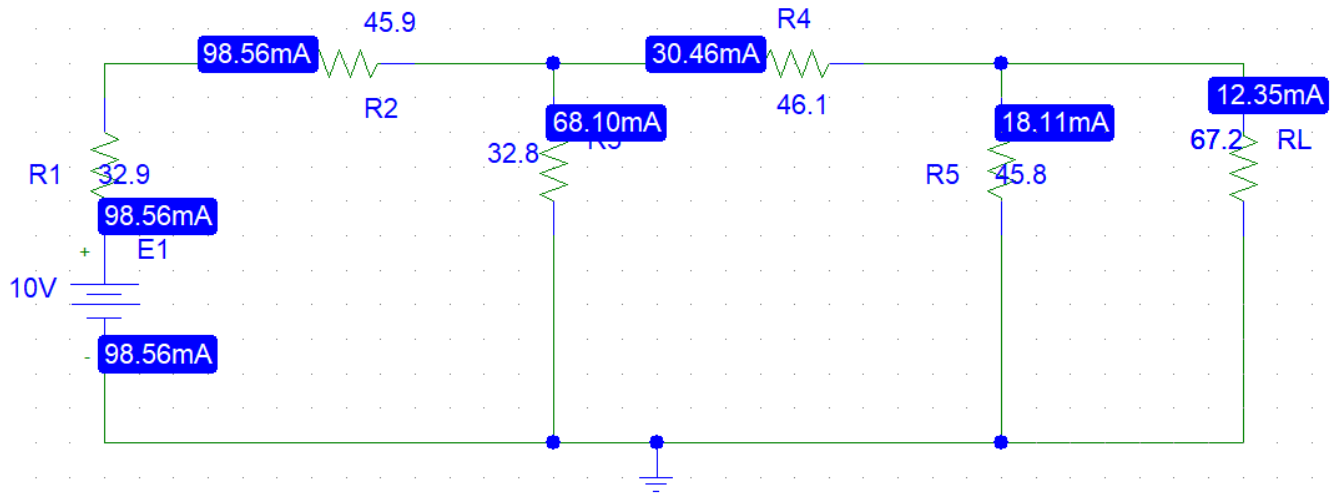


Figure 2: Circuit with E_1 source active

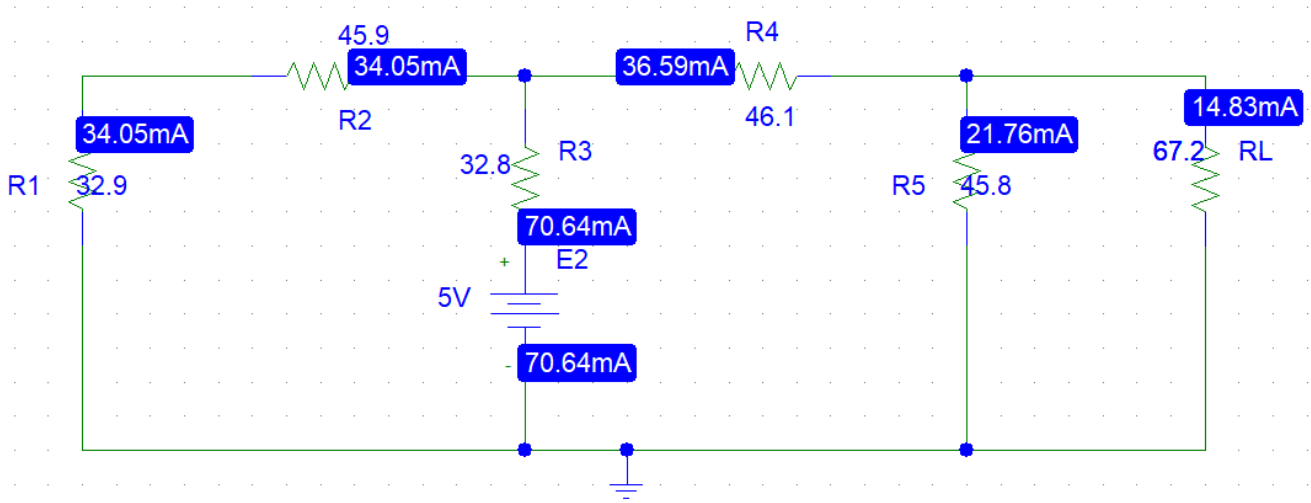


Figure 3: Circuit with E_2 source active

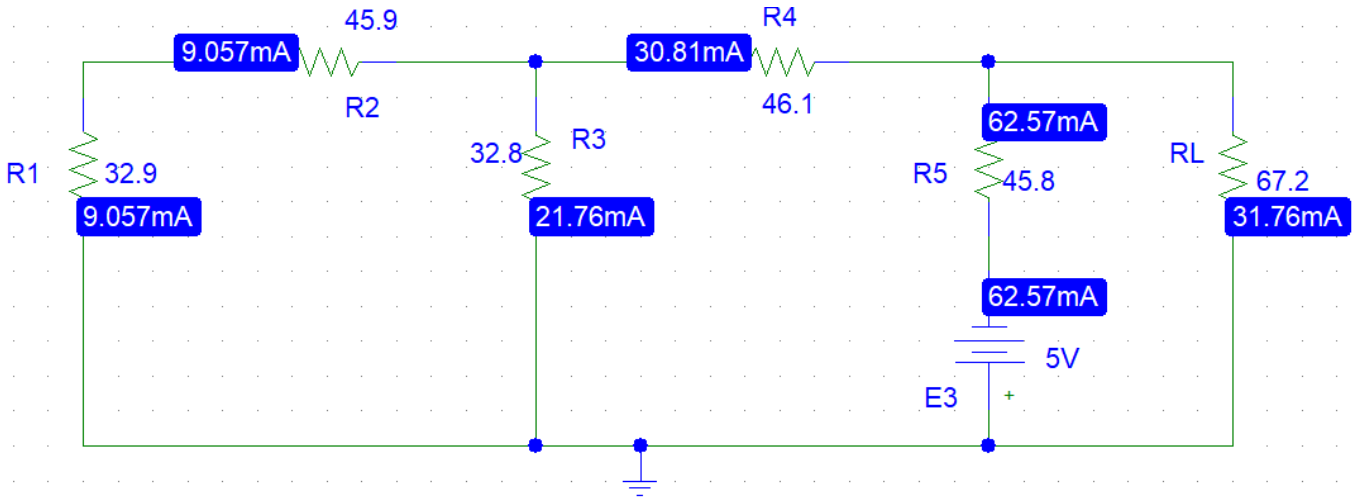


Figure 4: Circuit with E_3 source active

Here, I_{L1} = 12. 35 mA
I_{L2} = 14.83 mA
I_{L3} = 31.76 mA = - 31. 76 mA (At opposition direction)
So,
c = (12.35+ 14.83 − 31.76) mA = -4.58 mA = I_L

So, it holds the superposition theorem.

Comparison between PSpice solutions with the Theoretical solutions.

PSpice Values (mA)	Theoretical Values
I_L = - 4.58	I_L = -4.269
I_{L1}= 12.35	I_{L1} = 12.16
I_{L2}= 14.83	I_{L2} = 14.739
I_{L3} = -31.76	I_{L3} = -31.168

There is a discrepancy between PSpice solutions and the Theoretical solutions due to differences in resistor measurements.

Error Analysis:

Error of I_L = ((-4.269 – (- 4.58) / -4.269) *100 = -7.2 %

Error of I_{L1} = ((12.16 – 12.35)/12.16)*100 = -1.56 %

Error of I_{L2} = ((14.739 – 14.83)/14.739) * 100 = - 0.62 %

Error of I_{L3} = ((-31.168 – (-31.76)/ -31.168) *100 = -1. 89 %

Discussions:

1. It is needed to be ensured that all the connections are established according to the given circuit in the manual.

2. When measuring Thevenin resistance, it is needed to make sure that voltage sources are shorted and current sources are open to avoid incorrect resistance readings.

3. Same load resistance should be used for both the original circuit and the Thevenin equivalent circuit to ensure fair comparison of result.

4. It should be ensured that the circuit is correctly grounded to prevent any interference from affecting the result.