LABORATORY #6
MESH AND NODAL ANALYSIS OF A TWO-SOURCE DC NETWORK

Austin Guerrero
Lesley Osorio
ECE 263 Linear Circuit Theory I | Fall 2026 | October 12, 2026
Department of Electrical and Computer Engineering
Valparaiso University

ABSTRACT

In this laboratory, a two-source, six-resistor DC network was solved three ways: by hand with mesh analysis, in CircuitLab, and on a breadboard with a multimeter. Hand analysis and simulation agreed to within 0.05% on every node voltage and mesh current. The breadboard ran 0.6% to 2.9% higher than both, and nearly all of that gap traces to two causes: the bench supplies sat about 35 mV above 6 V, and every resistor measured below its nominal value. Re-solving the mesh equations with the measured source voltages and resistances brings every quantity to within 0.72% of the bench readings. The two sources delivered 108.4 mW in theory and 111.4 mW on the bench, and in both cases the six resistors absorbed all of it.

♦ INTRODUCTION

The goal of this lab is to find the mesh currents and node voltages of a linear DC network, then check those answers against a simulation and a physical circuit [1]. Mesh and nodal analysis both turn a circuit into a small system of linear equations. Solving that system is the easy part; the real test is whether a breadboard full of 5% resistors and a pair of bench supplies agrees with it.

The network in Fig. 1 holds two 6 V sources stacked in series and six resistors arranged into three meshes. The node voltages are labeled V_A through V_E, and the mesh currents I_1, I_2, and I_3. The bottom-left node serves as ground. The lab had three parts: predict every voltage and current by hand, simulate the circuit in CircuitLab, and build and measure it. The handout also asks for a power balance, so the power absorbed or delivered by each of the eight elements was calculated as well.

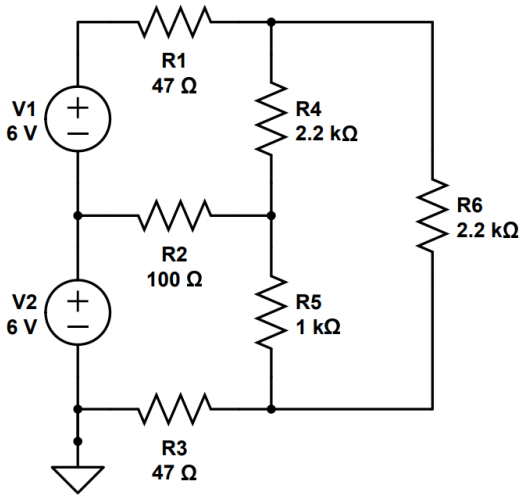


Fig. 1. ***DC circuit for mesh and nodal analysis [1]. Ground is the bottom-left node.***

♦ THEORY

Choosing Mesh Analysis

The handout allows either method, so the choice came down to which one needs fewer unknowns. The two sources fix V_A at 12 V and V_B at 6 V outright, which leaves three unknown node voltages (V_C, V_D, V_E) for nodal analysis. Mesh analysis also needs three equations, but neither source is shared between meshes, so each source simply appears on the right-hand side of its own

mesh. Mesh analysis was used, with all three currents taken clockwise:

- I_1 circulates through V1, R1, R4, and R2 (top left).
- I_2 circulates through V2, R2, R5, and R3 (bottom left).
- I_3 circulates through R4, R6, and R5 (right).

Mesh Equations

Applying KVL around each mesh with nominal resistor values gives

$$-6 + 47I_1 + 2200(I_1 - I_3) + 100(I_1 - I_2) = 0$$
$$-6 + 100(I_2 - I_1) + 1000(I_2 - I_3) + 47I_2 = 0$$
$$1000(I_3 - I_2) + 2200(I_3 - I_1) + 2200I_3 = 0$$

which collect into the system

$$2347I_1 - 100I_2 - 2200I_3 = 6$$
$$-100I_1 + 1147I_2 - 1000I_3 = 6$$
$$-2200I_1 - 1000I_2 + 5400I_3 = 0$$

Solving gives $I_1 = 7.747$ mA, $I_2 = 10.325$ mA, and $I_3 = 5.068$ mA. The full hand work is in Fig. 3 of the Appendix.

Node Voltages from Mesh Currents

Once the mesh currents are known, each node voltage follows from one source or one resistor drop:

$$V_A = V1 + V2 = 12\text{ V} \qquad V_B = V2 = 6\text{ V}$$
$$V_C = V_A - R1 \cdot I_1 \qquad V_D = V_B - R2(I_2 - I_1)$$
$$V_E = R3 \cdot I_2$$

A resistor shared by two meshes carries the difference of their currents. R2 carries $I_2 - I_1 = 2.578$ mA from node B toward node D, R4 carries $I_1 - I_3$, and R5 carries $I_2 - I_3$. R1, R3, and R6 each sit in a single mesh and carry I_1, I_2, and I_3.

Power

Each resistor absorbs $P = I^2R$. A source delivers $P = VI$ when current leaves its positive terminal, which is the case for both sources here. Conservation of energy requires the total absorbed power to equal the total delivered power.

♦ PROCEDURE

The procedure is given in the Lab 6 handout [1]. The simulation screenshot and the hand calculations are included in the Appendix.

I. All six resistors were measured with a digital multimeter before they went into the circuit (Table 1).

II. The network in Fig. 1 was built on a solderless breadboard.

III. The two DC sources were connected in series with help from the instructor, so that V1 sits on top of V2.

IV. The bottom-left node was taken as the reference, and the voltmeter's common lead stayed there for every reading.

V. Node voltages V_A through V_E were measured one at a time.

VI. An ammeter was inserted in series in a branch that carries only one mesh current (R1 for I_1, R3 for I_2, R6 for I_3). Each connection was checked by the instructor before the supplies were switched on.

VII. The circuit was rebuilt in CircuitLab with nominal values. Voltmeters and ammeters were placed at the same points to read all eight quantities (Fig. 2).

♦ RESULTS

Every resistor measured below its nominal value, by 1.3% to 3.6%, which is inside the ±5% tolerance band (Table 1). R5 was recorded on the data sheet as 9797.8 Ω; that is a misplaced decimal point for 979.78 Ω, since a 9.8 kΩ resistor would have cut I_2 and I_3 far below what the ammeter read. The bench supplies were not measured directly, but the node readings give them away: $V2 = V_B = 6.036$ V and $V1 = V_A - V_B = 6.035$ V.

Table 2 places all three sets of results side by side, with percent differences measured against the theoretical values. Table 3 lists the power of each element. Theoretical power uses nominal components; experimental power uses the measured mesh currents, the measured resistances for I^2R, and the measured source voltages for VI. Positive power is absorbed and negative power is delivered.

Table 1: Nominal and Measured Resistances

Resistor	Nominal (Ω)	Measured (Ω)	Deviation
R1	47	46.074	−1.97%
R2	100	96.405	−3.60%
R3	47	46.392	−1.29%
R4	2200	2165	−1.59%
R5	1000	979.78	−2.02%
R6	2200	2151.1	−2.22%

Table 2: Theoretical, Simulated, and Experimental Results

Quantity	Theoretical	CircuitLab	Experimental	Sim. vs. Theory	Exp. vs. Theory
V_A (V)	12.000	12.00	12.071	0.00%	+0.59%
V_B (V)	6.000	6.000	6.0364	0.00%	+0.61%
V_C (V)	11.636	11.64	11.7013	+0.04%	+0.56%
V_D (V)	5.742	5.742	5.7743	0.00%	+0.56%
V_E (V)	0.4853	0.4853	0.49407	0.00%	+1.81%
I_1 (mA)	7.747	7.747	7.923	0.00%	+2.27%
I_2 (mA)	10.325	10.33	10.5335	+0.04%	+2.02%
I_3 (mA)	5.068	5.068	5.2126	0.00%	+2.85%

Table 3: Power Absorbed (+) and Delivered (−) by Each Element

Element	Current, Theory (mA)	Power, Theory (mW)	Current, Exp. (mA)	Power, Exp. (mW)
V1	7.747	−46.48	7.923	−47.81
V2	10.325	−61.95	10.534	−63.58
R1 (47 Ω)	7.747	+2.82	7.923	+2.89
R2 (100 Ω)	2.578	+0.66	2.611	+0.66
R3 (47 Ω)	10.325	+5.01	10.534	+5.15
R4 (2.2 kΩ)	2.679	+15.79	2.710	+15.91
R5 (1 kΩ)	5.257	+27.64	5.321	+27.74
R6 (2.2 kΩ)	5.068	+56.52	5.213	+58.45
Total delivered		**108.44**		**111.40**
Total absorbed		**108.44**		**110.79**

♦ DISCUSSION

Theory and Simulation

The hand solution and CircuitLab agree on all eight quantities to within 0.05%, and those small gaps are rounding in the simulator's display. That is the expected result: both solve the same linear system with the same ideal parts. The simulation does not prove the circuit works; it proves the algebra was done correctly, which is still worth knowing before touching a breadboard. The CircuitLab schematic in Fig. 2 numbers its resistors differently from the handout (its R4 is the handout's R1, for example), but the values and positions match.

Experiment versus Theory

The breadboard readings run 0.6% to 2.9% above theory, and they all err in the same direction. A random error would scatter both ways, so a consistent shift points to something systematic. There are two:

- **Source voltage.** Both supplies sat about 0.6% high, at 6.035 V and 6.036 V. In a linear circuit every voltage and current scales directly with the sources, so this alone lifts every reading by about 0.6%. It accounts for nearly all of the error in V_A through V_D.
- **Resistor values.** Every resistor came in 1.3% to 3.6% low. Lower resistance means more current, which explains why the three mesh currents and V_E (which equals R3 times I_2) sit roughly 2% higher than the voltages do.

The best test of that explanation is to put the real values back into the mesh equations. Re-solving with the measured resistances and source voltages gives the predictions in Table 4.

Table 4: Experimental Results versus Theory Using Measured Components

Quantity	Theory (meas. parts)	Exp.	Diff.
V_C (V)	11.7048	11.7013	−0.03%
V_D (V)	5.7799	5.7743	−0.10%
V_E (V)	0.4922	0.49407	+0.38%
I_1 (mA)	7.949	7.923	−0.33%
I_2 (mA)	10.609	10.5335	−0.72%
I_3 (mA)	5.212	5.2126	0.00%

Every difference drops below 0.72%. The model was right all along; it was just being fed the labels on the parts instead of the parts themselves.

The leftover error has a pattern of its own. I_3 was read in series with R6, a 2.2 kΩ branch, and matches to four digits. I_1 and I_2 were read in series with the 47 Ω resistors, and both read slightly low. An ammeter adds its own small internal resistance to the branch it measures. A fraction of an ohm is nothing next to 2.2 kΩ, but it is about 1% of 47 Ω, which is the right size to explain the 0.3% to 0.7% shortfall. Breadboard contact resistance adds to the same low-resistance branches in the same way.

Power Balance

The power delivered does equal the power absorbed. In theory, the two sources deliver 108.44 mW and the six resistors absorb exactly 108.44 mW (Table 3). On the bench, the sources delivered 111.40 mW and I^2R across the measured resistances accounts for 110.79 mW, a gap of 0.55%. That gap comes from the same ammeter burden described above, since I^2R squares any error in the measured current. Computing each resistor's power from its measured voltage drop instead closes the balance completely, as Tellegen's theorem requires of any set of readings that obey KVL and KCL.

The table also shows where the energy goes. R6 alone absorbs 52% of the total, and the three kilohm resistors together take 92%. The 47 Ω resistors carry the largest currents in the circuit yet absorb little power; their resistance is roughly 50 times smaller, and the current is only about twice as large. V2 delivers more than V1 for a simple reason: both sit at 6 V, and I_2 is larger than I_1.

Problems Encountered

The circuit itself was straightforward to build. The main hazard was the ammeter: placing it in parallel instead of in series would have shorted a branch. Having the instructor check each ammeter connection before power-up, as the handout requires, prevented that. The one recording error, the R5 value logged as 9797.8 Ω, was caught during analysis because it contradicted the measured currents; a quick sanity check against the nominal value at the bench would have caught it sooner.

♦ CONCLUSION

Mesh analysis predicted every node voltage and mesh current in the network, and CircuitLab confirmed the hand solution to within 0.05%. The breadboard read 0.6% to 2.9% high across the board. That offset came from supplies set about 35 mV above 6 V and resistors that ran 1% to 4% below nominal, not from any flaw in the analysis; with the measured values plugged in, the

predictions land within 0.72% of the bench. Power balanced in both cases, at 108.44 mW in theory and 111.40 mW on the bench. The lab's quiet lesson is that a model is only as good as its inputs. The equations were correct from the start; the parts drawer simply had its own opinion about what 47 Ω means.

♦ ACKNOWLEDGEMENTS

The circuit was built and tested with my lab partner, Lesley Osorio. The objective, procedure, and report requirements were given and paraphrased from the ECE 263 Lab 6 handout [1]. The instructor assisted with connecting the two DC sources and verified the ammeter placement before power-up.

♦ REFERENCES

[1] Dept. of Electrical and Computer Engineering, *ECE 263: Linear Circuit Theory I, Lab 6: Mesh and Nodal Analysis*. Valparaiso, IN, USA: Valparaiso University.

[2] CircuitLab, Inc., *CircuitLab* [Online circuit simulator]. Available: https://www.circuitlab.com

APPENDIX

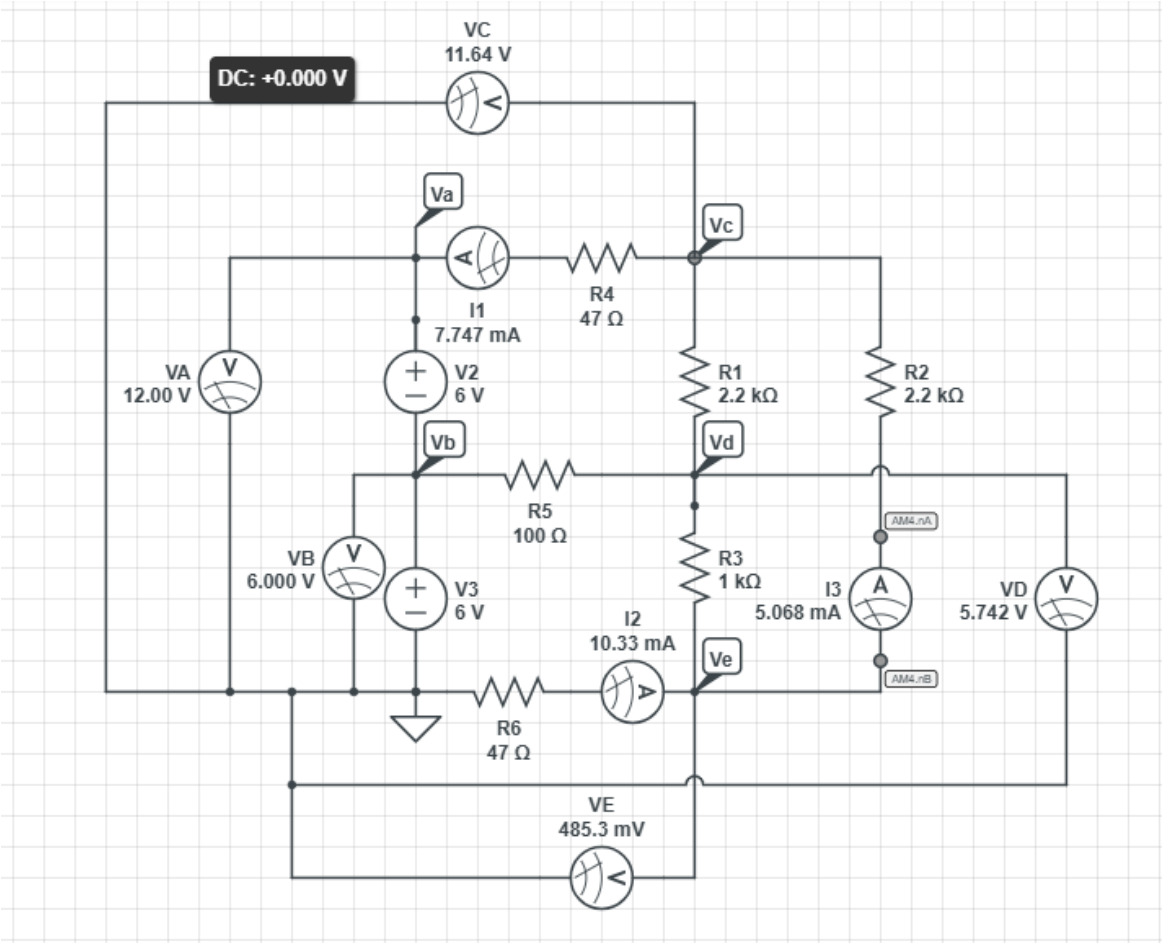


Fig. 2. ***CircuitLab simulation with voltmeters at each node and ammeters in each mesh [2]. Resistor labels differ from the handout; values and positions match.***

APPENDIX

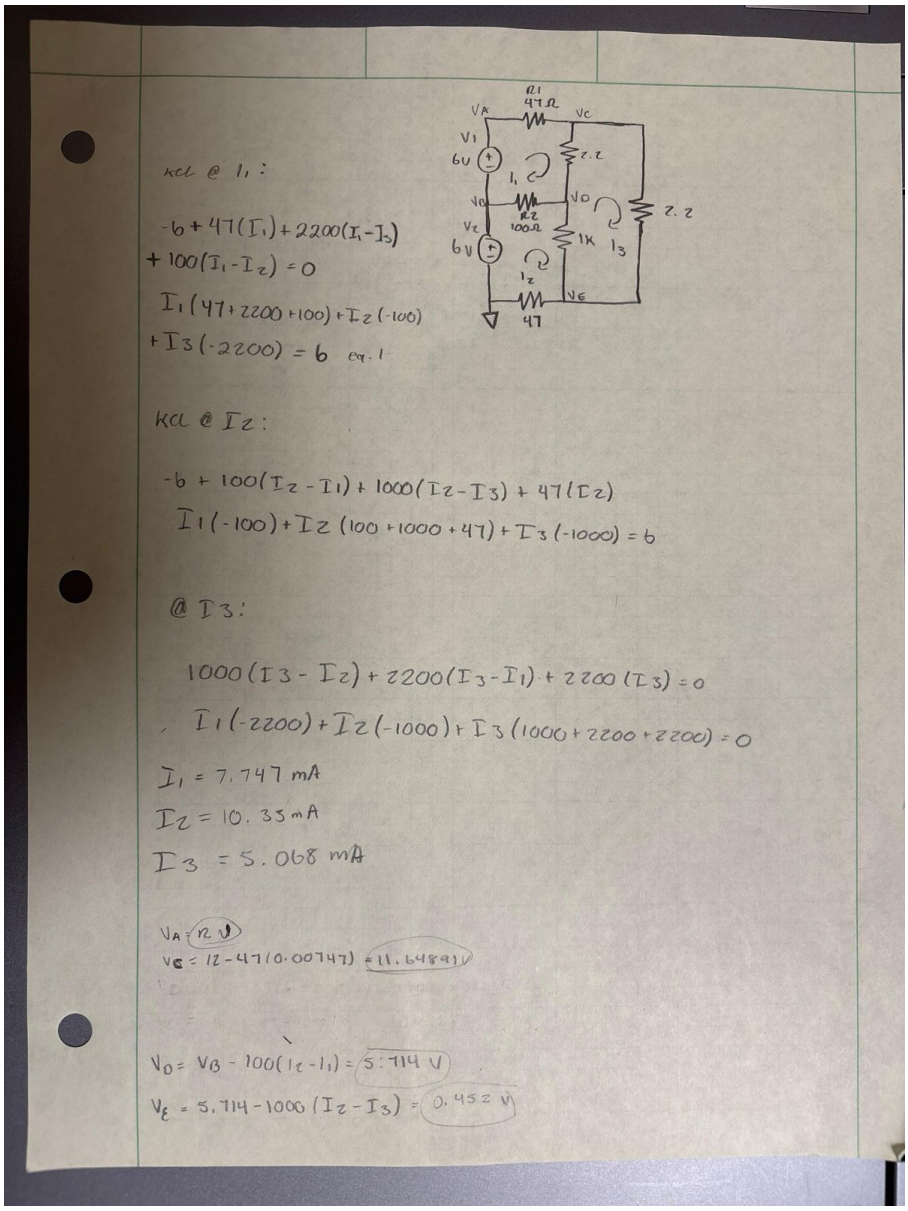


Fig. 3. ***Hand calculations: mesh equations, solved mesh currents, and node voltages.***