

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING: A CONVERSATIONAL APPROACH

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The engineering workflow you will use throughout this book

CHAPTER - 8

PART 5 · ≈ 30 MIN

A Correct Solution to the Wrong Model

MATLAB solves the equations. The residual is zero. The voltages look reasonable. And the prediction is still wrong. Part 5 asks what the solver can check — and what only the engineer, and the experiment, can.

5

Problem

›

Model

›

Compute

›

Analyze

›

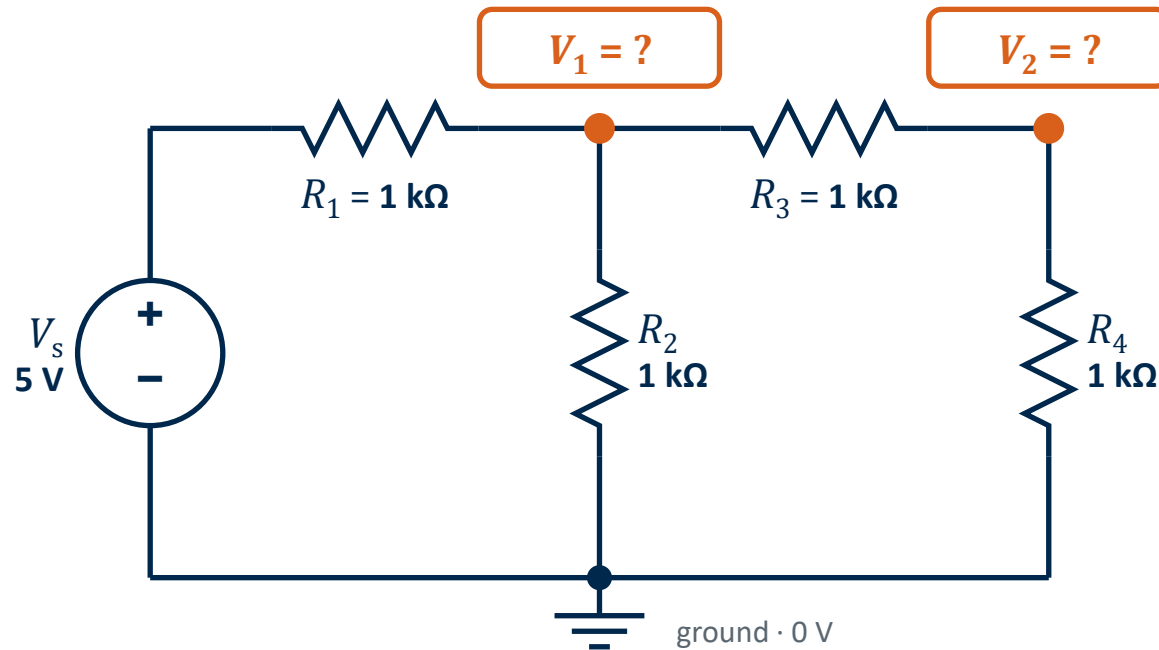
Validate

›

Improve



Two answers. Both have zero residual.



The original circuit from Parts 1–3. 5 V source, four 1 kΩ resistors.

MODEL A

$$V_1 = 2.000 \text{ V}$$

$$V_2 = 1.000 \text{ V}$$

residual $\approx 0 \text{ mA}$ ✓

MODEL B

$$V_1 = 3.333 \text{ V}$$

$$V_2 = 1.667 \text{ V}$$

residual $\approx 0 \text{ mA}$ ✓

ASK THE ROOM

Which prediction should we trust?

What additional information would you need to decide?

Both were solved correctly by MATLAB. At most one of them can describe this circuit.

Problem



Model



Compute



Analyze



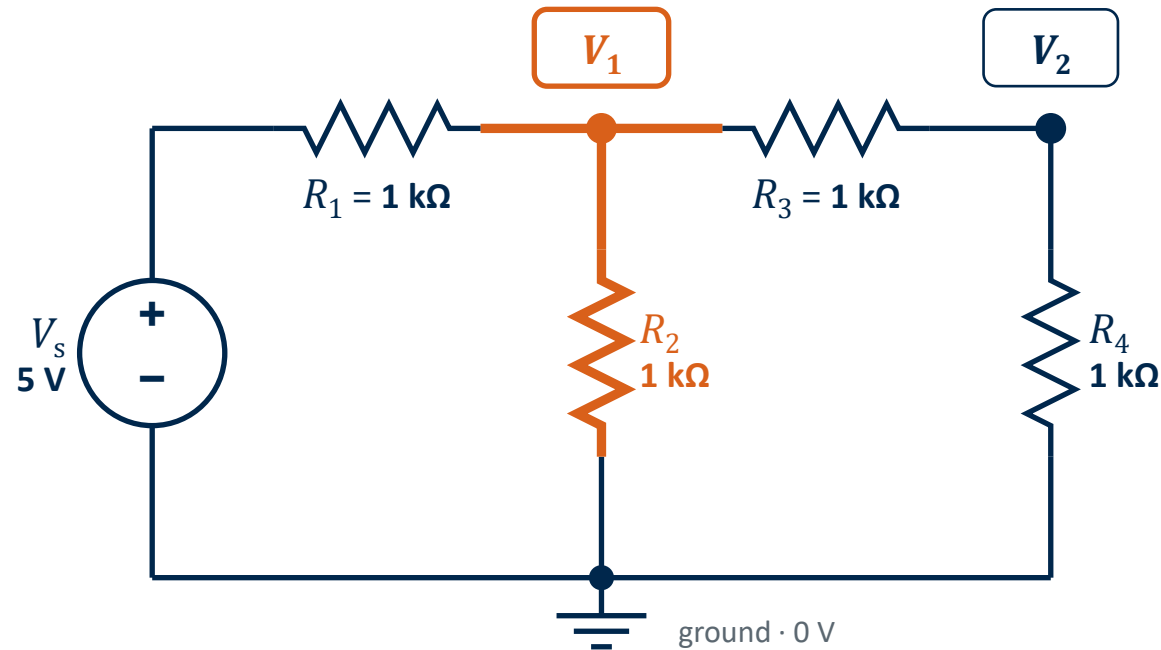
Validate



Improve



Find the missing physics



Three resistors touch node **V1**: R1, R2 and R3. Model B kept only two of them.

$$A_A = \begin{bmatrix} \boxed{3} & -1 \\ -1 & 2 \end{bmatrix} \quad A_B = \begin{bmatrix} \boxed{2} & -1 \\ -1 & 2 \end{bmatrix}$$

a_{11} Model A: $1 + 1 + 1 = 3 \text{ mS}$ (R1, R2, R3)

a_{11} Model B: $1 + 1 = 2 \text{ mS}$ — **R2 is missing**

ASK THE ROOM

Trace it on the circuit: which current path out of V1 is missing from Model B?

Every physical current path must appear in its node equation.

The solver cannot add a resistor the engineer left out. Model B omitted R2 — V1's path to ground.

Problem



Model



Compute



Analyze



Validate



Improve



A zero residual can still be misleading

```
b = [5; 0];  
A_correct = [3 -1; -1 2];  
A_wrong   = [2 -1; -1 2];  
  
V_correct = A_correct\b;  
V_wrong   = A_wrong\b;  
  
r_correct = A_correct*V_correct - b  
r_wrong   = A_wrong*V_wrong - b  
  
% check Model B against the intended circuit  
r_physical = A_correct*V_wrong - b
```

VS THEIR OWN EQUATIONS

$r_{\text{correct}} \approx [0; 0] \text{ mA}$

$r_{\text{wrong}} \approx [0; 0] \text{ mA}$

Both pass. Each answer satisfies the equations it was solved from.

MODEL B VS THE INTENDED CIRCUIT

$r_{\text{physical}} = [3.3333; 0] \text{ mA}$

10/3 mA missing at V1 — exactly the current R2 would carry at 3.333 V.

REVIEW NOTE Residual $\neq$ correctness

A residual tests only the equations used to compute it.

A residual checks the equations used to compute it — not whether they are the right equations.

Problem



Model



Compute



Analyze



Validate



Improve



Would a plausibility check have caught it?

Check	Model A (2.000, 1.000 V)	Model B (3.333, 1.667 V)
$0\text{ V} < V_2 < V_1 < 5\text{ V}$	✓	✓
Current in R3 flows from V1 toward V2	✓	✓
Both node voltages positive	✓	✓
Residual ≈ 0 against its own matrix	✓	✓

REVIEW NOTE Plausibility is not validation

A plausibility check rejects results that are obviously impossible. Passing it does not prove a model is correct — Model B passes every check above.

ASK THE ROOM

If both predictions look physically reasonable, how can we decide which model is appropriate?

Plausible is not the same as correct. Both models pass every check in this table.

Problem ›

Model ›

Compute ›

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The AI answer looks convincing

SIMULATED AI RESPONSE

"I derived the nodal equations and solved them in MATLAB. [1] The solution is $V1 = 3.333\text{ V}$ and $V2 = 1.667\text{ V}$. The residual is zero, confirming the model is correct. [2] Both voltages are below the supply voltage, so the results are physically valid." [3]

Illustrative text written for this lesson — not the output of a real AI session.

1 **"derived the nodal equations"**
Which resistors are in the V1 equation?

2 **"residual is zero, confirming the model"**
What does a residual actually test?

3 **"below the supply, so physically valid"**
Is a plausible range proof?

Not an AI-only problem. A human engineer could omit R2 too. The danger is accepting a polished explanation without checking it.

Confident is not the same as correct. Which claims are supported by evidence — and which are not?

Problem



Model



Compute



Analyze



Validate



Improve



Interrogate the AI: what would you ask next?

ASK THE ROOM

Write the prompt you would send next — one that challenges the reasoning, not just the number.

WEAK FOLLOW-UP

“Please recalculate V_1 and V_2 and check your answer.”

The AI can re-solve the same wrong matrix and return the same answer — now with more confidence.

A BETTER PROMPT (after discussion)

“Reconstruct the nodal equations directly from the circuit. List every resistor connected to each node, identify each current term, and explain how each term appears in the coefficient matrix. Do not solve the system until the equations have been checked.”

Why it works: it asks for traceability — circuit $\rightarrow$ currents $\rightarrow$ matrix — so the missing R2 has nowhere to hide. You still check every line yourself.

THINK $\rightarrow$ PSEUDOCODE $\rightarrow$ AI $\rightarrow$ CODE. Interrogate the model and its assumptions, not only the answer.

Problem



Model



Compute



Analyze



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Improve



When the matrix cannot determine an answer



No source. No ground. Nothing fixes the voltage of either node.

$$\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Both rows say $V_1 - V_2 = 0$. The pairs (0, 0), (2, 2) and (100, 100) V all satisfy it — infinitely many solutions, no unique answer.

REVIEW NOTE Singular matrix

A matrix that cannot determine a unique solution for every right-hand side. Here a missing voltage reference leaves the absolute node voltage undetermined.

READ THE WARNING AS PHYSICS

MATLAB warns that the matrix is singular. Read it as: **a physical constraint is missing** — here, a reference. Grounding one node (0 V) restores a unique answer.

A solver warning can be a modeling message. No reference, no unique voltages — ground is not optional.

Problem



Model



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Improve



What would you check before trusting a prediction?

1 Topology: Does the model represent the actual connections? **MODEL INSPECTION** catches R2

2 Physics: Are all conservation equations correctly formulated? **MODEL INSPECTION** catches R2

3 Units and signs: Are values and directions consistent? **MODEL INSPECTION**

4 Computation: Does the solution satisfy the supplied equations? **NUMERICAL VERIFICATION** misses R2

5 Plausibility: Are the predictions physically reasonable? **SANITY FILTER** misses R2

6 Experiment: Do measured results support the model? **EXPERIMENTAL VALIDATION** Lab 8

REVIEW NOTE V & V

Verification: did we solve the equations right?

Validation: did we solve the right equations — does reality agree?

Checks 1–5 prepare for check 6.
None of them replaces it.

Inspection and verification prepare for validation — they cannot replace it.

Problem



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The solver did its job. Did we do ours?



✓ Physical coupling creates simultaneous equations.

✓ Conservation laws determine the matrix structure.

✓ Gauss-Jordan and MATLAB solve the equations.

✓ Parameter changes and new nodes expand the system.

✓ **Numerical consistency does not guarantee physical correctness.**

✓ **Engineers inspect assumptions and seek physical evidence.**

THE LAB 8 CHALLENGE

Your MATLAB model predicts three node voltages. Your multimeter reports different values.

What evidence should you gather before deciding whether the model or the experiment needs correction?

Next: Lab 8 — build the network, measure it, extend it, and compare the meter with the model.

The computer solves the equations we give it. The engineer decides whether they describe the system.



Coupled unknowns must be found together.

Conservation laws build the matrix.

A solver solves exactly the model we give it.

A near-zero residual confirms consistency with the equations—not the correctness of the physical model.

Plausible is not the same as correct.

A missing reference is missing physics.

Only evidence from the real system validates a model.

SOLVED $\neq$ VALIDATED

THE COMPUTER SOLVES.
THE ENGINEER INSPECTS.
THE EXPERIMENT DECIDES.

Part 1 asked: what would convince you that a computer's answer is right? **Now you can name the evidence — and the evidence a computer cannot supply.**

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