

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING: A CONVERSATIONAL APPROACH

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The engineering workflow you will use throughout this book

CHAPTER - 8

PART 1 · ≈ 25 MIN

When One Equation Is Not Enough

Four resistors, one 5 V source, two unknown voltages. Every component is known — yet one voltage cannot be found without the other. Chapter 7 fitted ONE model to measured data; Chapter 8 asks how quantities that depend on one another are found together.



Problem

Model

Compute

Analyze

Validate

Improve

When unknown quantities depend on one another, how do we predict them — and how would we know the computed answer describes the real system?

Commit to a first answer before we start: what would convince YOU that a computer's answer is right? **It ran without errors · the numbers look reasonable · it matches a measurement · something else?**

Problem

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CONTENTS OF CHAPTER 8:

Chapter 7 asked: what one model should speak for all the measured points? **Chapter 8 asks:** when several unknowns depend on one another, how do we find them together — and should we trust the answer?

1

When one equation is not enough · you are here

A resistor network · what we know, what we must find · why V1 cannot be found without V2



2

From physical laws to a matrix

Ohm's law and conservation of current · two node equations · what each number in the matrix means



3

Solve it by hand, then let the computer solve it

Gauss-Jordan elimination · MATLAB's backslash · what a small residual does — and does not — prove



4

When the system changes and grows

Your R4 prediction, tested · from two unknowns to three · same matrix, different physics



5

A correct solution to the wrong model

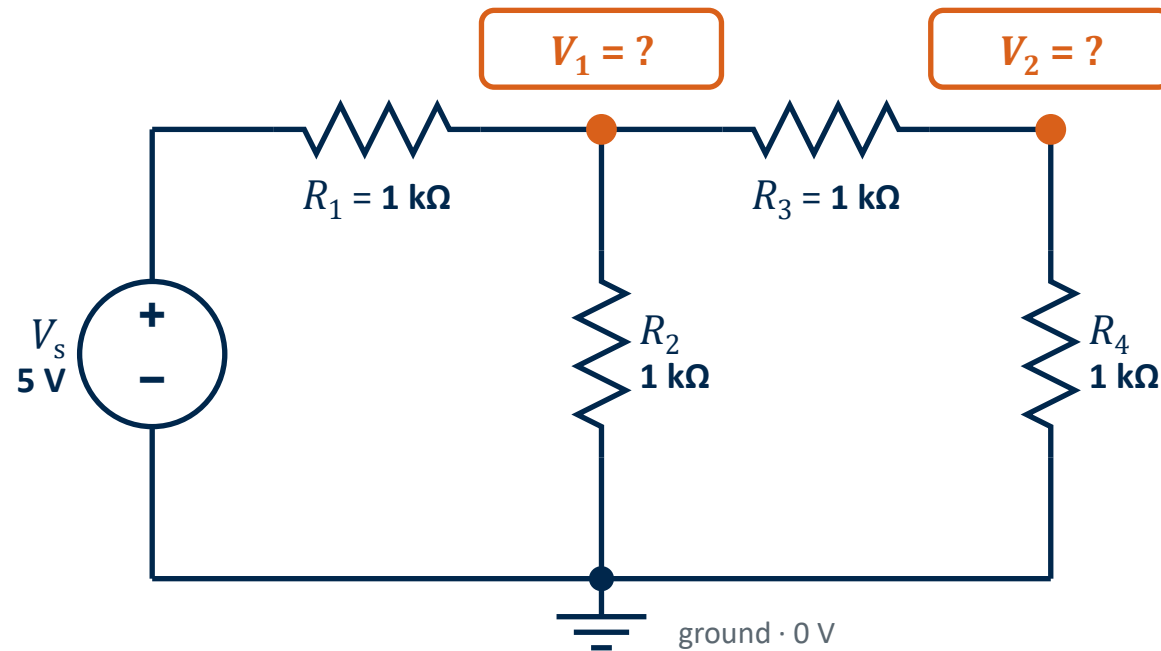
Errors a solver cannot see · verification versus validation · questioning AI-generated equations



Course spiral: Ch 4–5 — one unknown, one equation (root finding) · Ch 7 — a residual compared a model with data · Ch 8 — several coupled unknowns, solved together · Ch 9 — the same systems, solved by iteration. Prediction before computation, as always.



We know every part. Can one equation predict the voltages?



Read it left to right: source $\rightarrow$ $R_1 \rightarrow$ node V_1 , which splits two ways: R_2 down to ground, and R_3 on to node $V_2 \rightarrow R_4$ down to ground.

THE SYSTEM

A 5 V DC source drives current through four 1 k Ω resistors and back to ground. **Every component value is known.**

The voltages at two points — V_1 and V_2 — are not.

ASK THE ROOM

Could you write **ONE** equation that gives V_1 directly?

If not — what else would you need to know first?

Knowing the parts is not the same as knowing the behavior. Today: find out why. No solving yet.

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A circuit is a physical system: four ideas carry this chapter

VOLTAGE

V · volts (V)

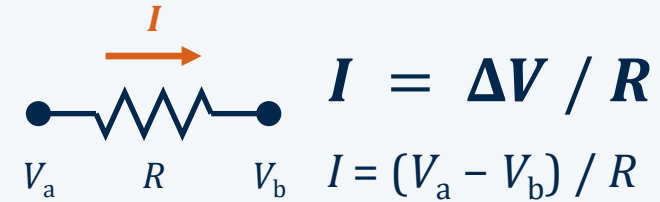
The electrical "height" of a point. Only a DIFFERENCE in voltage between two points drives current.

CURRENT

I · milliamps (mA)

The rate at which charge flows through a component. We draw an arrow for its assumed direction.

OHM'S LAW · ONE RESISTOR



Current flows from the higher-voltage end to the lower-voltage end. **Units that fit: volts ÷ kilohms = milliamps.**

RESISTANCE

R · kilohms (kΩ)

How strongly a component opposes current. Larger $R \rightarrow$ less current for the same voltage difference.

GROUND

0 V · the reference

The point WE choose as zero. Every node voltage, like V_1 , is measured from ground — like heights from a floor.

REVIEW NOTE A useful analogy — and its limit

Voltage $\approx$ water height · current $\approx$ flow rate · resistor $\approx$ narrow pipe.

Limit: a resistor does not use up current — the same current leaves it as enters it. What drops across a resistor is voltage (energy per charge).

Ohm's law needs a voltage DIFFERENCE. One resistor, two ends, two voltages — remember this at R3.

Problem



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How to read the schematic — and what a node really is



DC voltage source

Holds its + terminal a fixed voltage above its – terminal (here 5 V).



Resistor

Opposes current. Labelled with its name and value, e.g. $R_1 = 1\text{ k}\Omega$.



Wire

Treated as perfect (no resistance): every point on it has the same voltage.



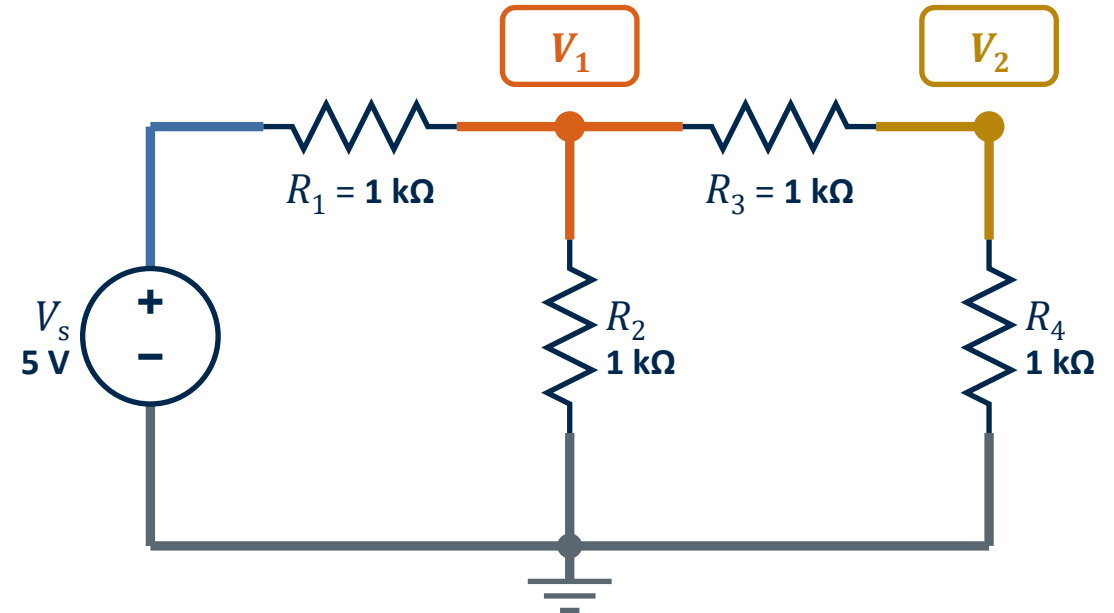
Node dot

Marks a junction where three or more connections meet.



Ground

The shared 0 V reference. Every voltage is measured from it.



— +5 V node: fixed by the source — node V1

— node V2

— ground node: 0 V

One node = one voltage. Everything joined by wire, with no component in between, is the same node.

Problem



Model



Compute



Analyze



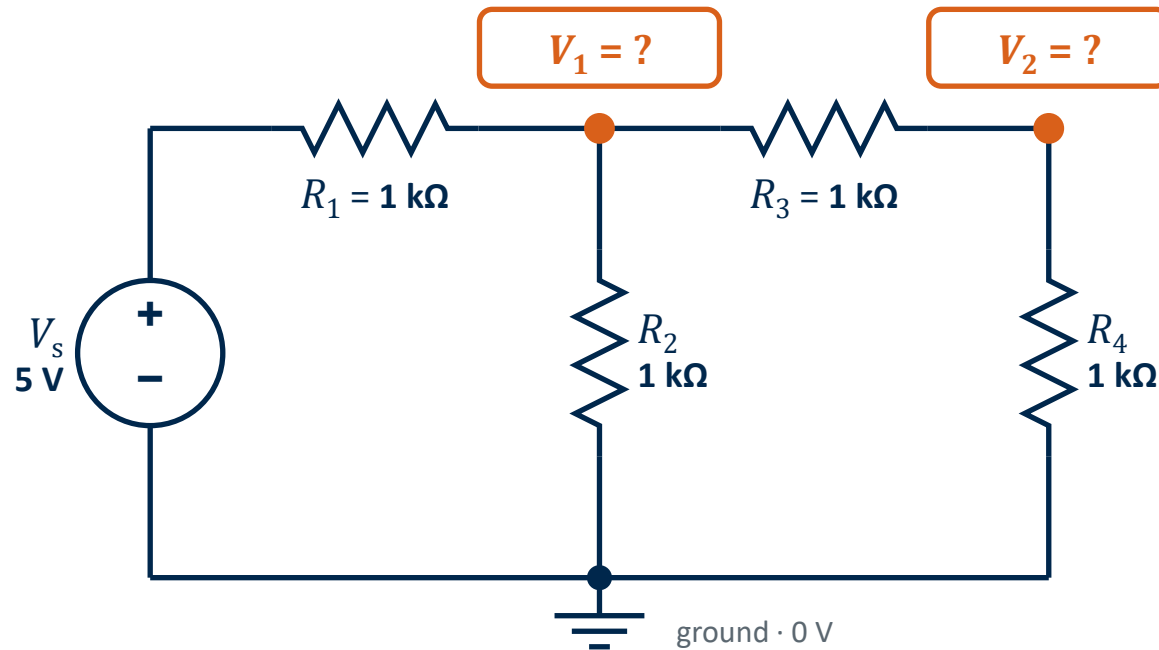
Validate



Improve



Two unknowns, measured from ground



Orange: unknown node voltages, each measured relative to ground. Everything else on the drawing is given.

KNOWN

$V_s = 5 \text{ V}$ (+ terminal 5 V above ground)
 $R_1 = R_2 = R_3 = R_4 = 1 \text{ k}\Omega$
 ground = 0 V (our choice of reference)

MUST FIND

V_1 and V_2 — two node voltages

ASK THE ROOM

1. The four resistor currents are unknown too. Why count only TWO unknowns?
2. Can V_1 be found without considering V_2 ?

Choose the unknowns wisely. Find the node voltages — every current then follows from Ohm's law.

Problem

Model

Compute

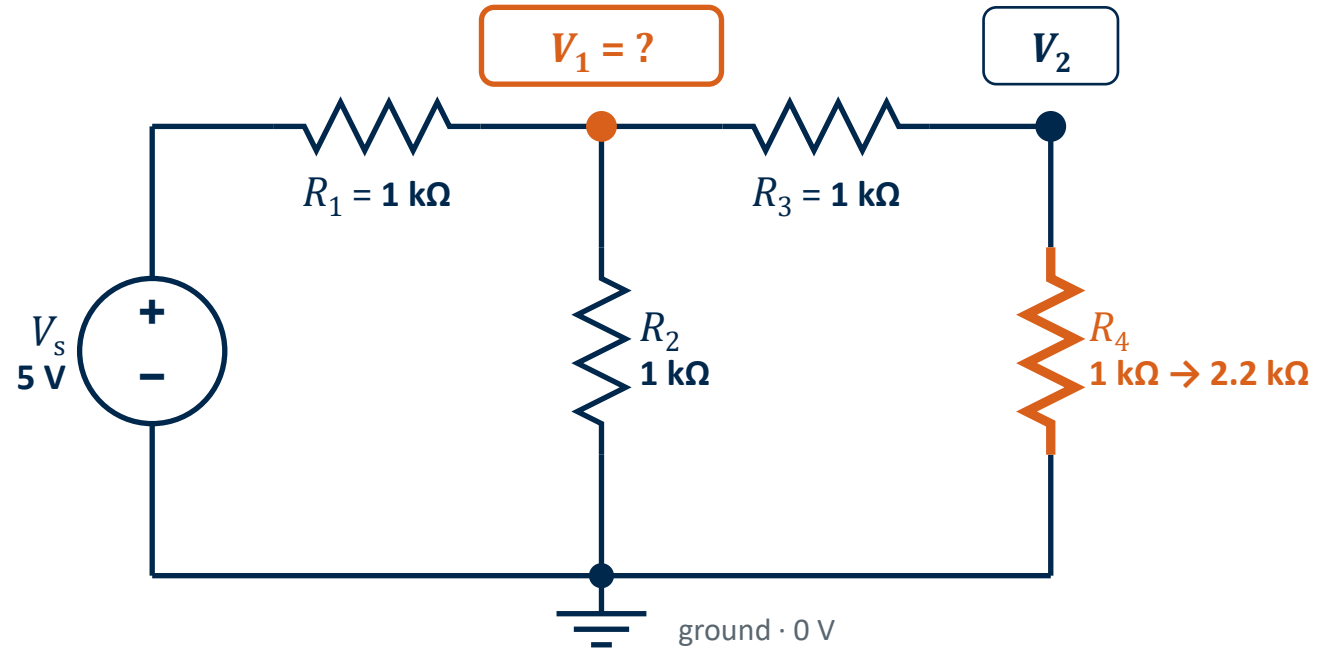
Analyze

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Improve



PREDICT



R4 sits on the far side of the network. It does not touch node V1 at all.

If R_4 increases from $1\text{ k}\Omega$ to $2.2\text{ k}\Omega$, what happens to V_1 ?

- A** V_1 increases
- B** V_1 decreases
- C** V_1 stays the same

Write your letter and one physical reason. No calculation. A guess with a reason beats a correct letter without one.

Commit now — and keep your answer. Part 4 returns to this exact question.

Problem



Model



Compute



Analyze



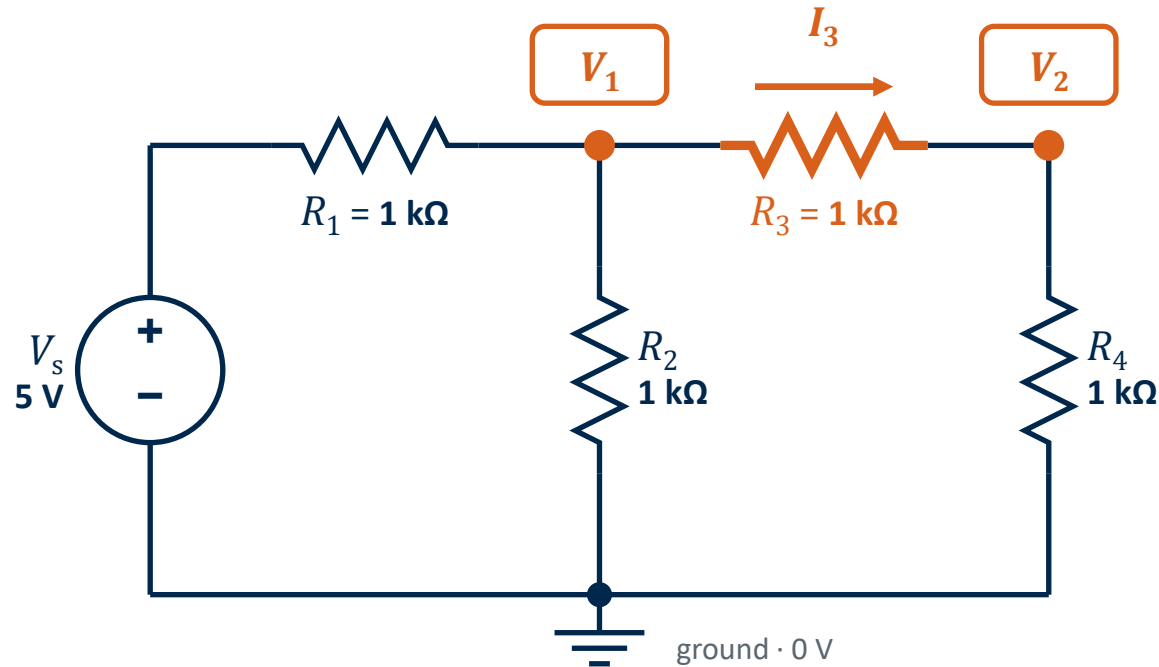
Validate



Improve



Try to determine V1: start with the current through R3



Assumed direction: from V1 toward V2 — chosen before we know the answer.

OHM'S LAW FOR R3

$$I_3 = (V_1 - V_2) / R_3$$

Voltage at the arrow's tail minus voltage at its head, divided by the resistance.

ASK THE ROOM

To calculate I_3 , what must you already know?

REVIEW NOTE

Assumed current direction

We pick the arrow first. If I_3 comes out negative, current really flows from V_2 to V_1 — the equation is still right.

The current in R3 depends on BOTH unknowns. R3 couples V1 to V2 — the central discovery of Part 1.

Problem



Model



Compute



Analyze



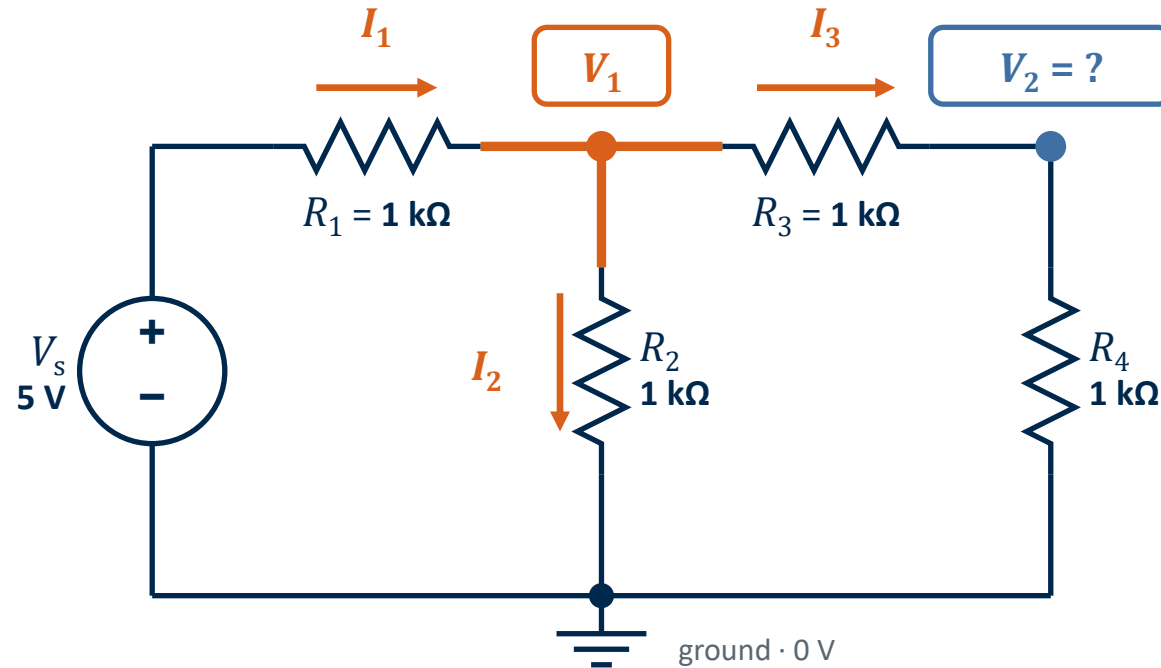
Validate



Improve



Balance the currents at V1 — and V2 is still there



Orange wire: the V1 node. One current arrives (I_1); two leave (I_2 and I_3).

AT NODE V1: IN = OUT

$$I_1 = I_2 + I_3$$

I_1 depends on V_1 (V_s is known)

I_2 depends on V_1

I_3 depends on V_1 and V_2

ASK THE ROOM

One balance, two unknowns. Where could a second, **independent** relationship come from?

REVIEW NOTE Conservation of current

Charge cannot pile up at a junction: current in = current out.
Part 2 names it Kirchhoff's Current Law.

One equation cannot pin down two unknowns. The circuit has a second node waiting to be asked: V2.

Problem



Model



Compute



Analyze



Validate



Improve



Two unknowns. Two relationships. One system.

BALANCE AT NODE V1

$$f_1(V_1, V_2) = 0$$

current in = current out at V1

BALANCE AT NODE V2

$$f_2(V_1, V_2) = 0$$

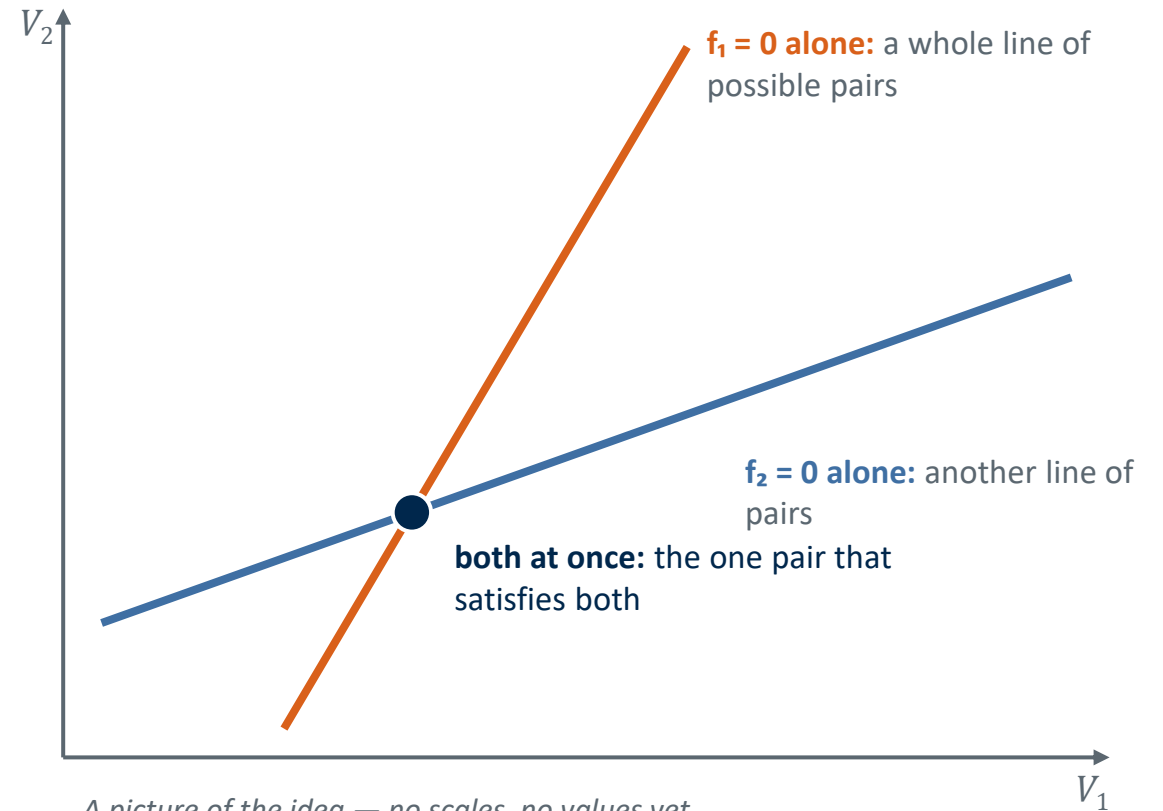
current in = current out at V2

TEST A CANDIDATE

Suppose $V_1 = V_2 = 2.5$ V. This pair balances node V1.

Can node V2 balance too?

Hint: what is I_3 ? Where would R4's current come from?



A picture of the idea — no scales, no values yet.

Simultaneous means both at once. Neither balance alone fixes the voltages. Together they do.

Problem



Model



Compute



Analyze



Validate



Improve



The physics gives us the equations

PHYSICAL CONNECTIONS ›

COUPLED UNKNOWN ›

CONSERVATION AT EACH
NODE ›

SIMULTANEOUS EQUATIONS

WE KNOW

every component: $V_s = 5\text{ V}$, four $1\text{ k}\Omega$ resistors, ground = 0 V .

WE FOUND

R3 ties V_1 to V_2 . Neither can be found on its own.

WE NEED

one physical relationship per unknown node — all of them satisfied **together**.

NEXT — PART 2 · FROM PHYSICAL LAWS TO A MATRIX

How can we organize these relationships so that a computer can solve them reliably?

Part 2 writes both node balances in full from Ohm's law and conservation of current — then arranges them into one organized form a computer can work with.

Your R4 prediction is still open. Keep it — Part 4 will put it to the test.

Problem ›

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