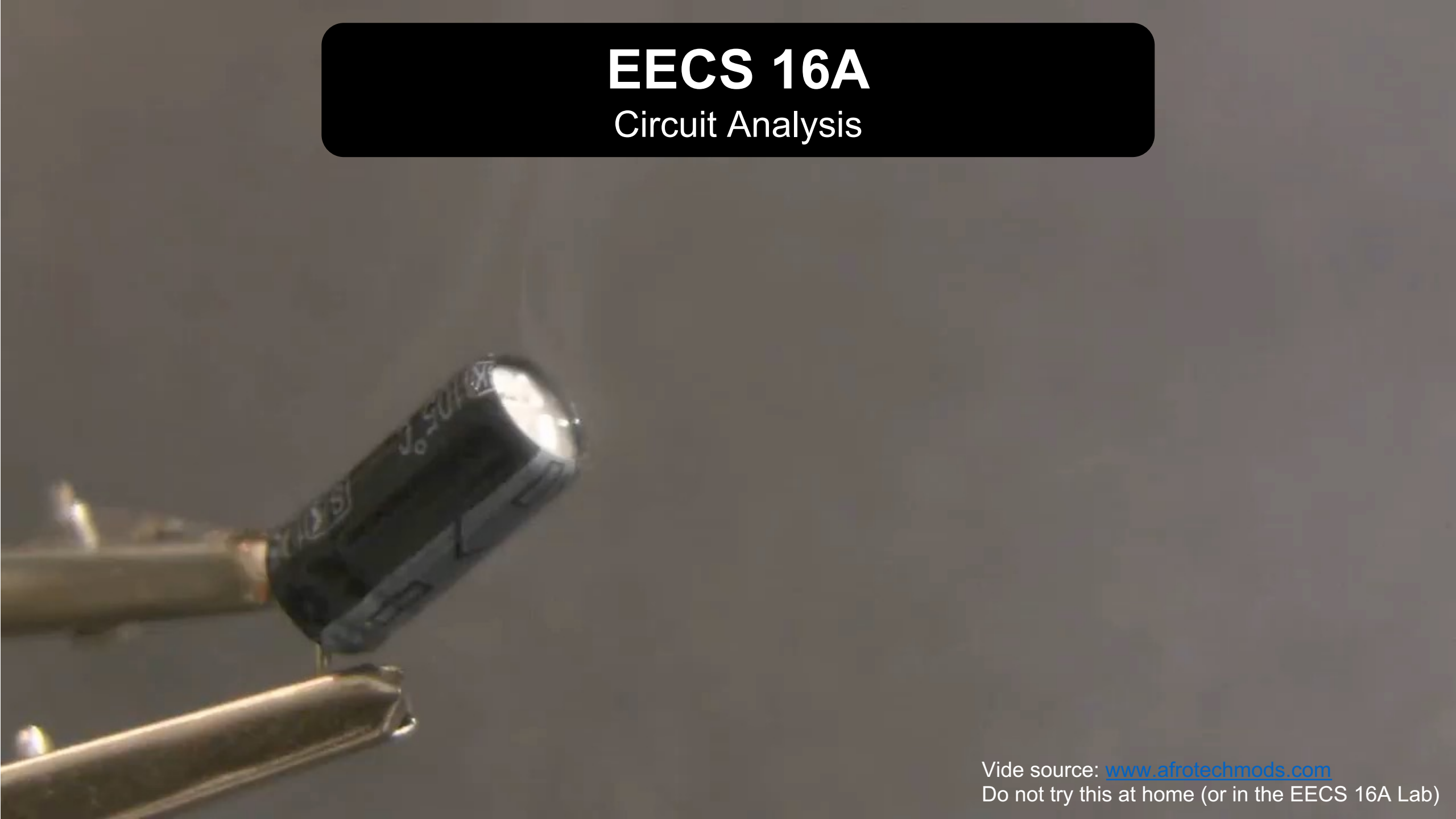
EECS 16A

Circuit Analysis



Vide source: www.afrotechmods.com
Do not try this at home (or in the EECS 16A Lab)

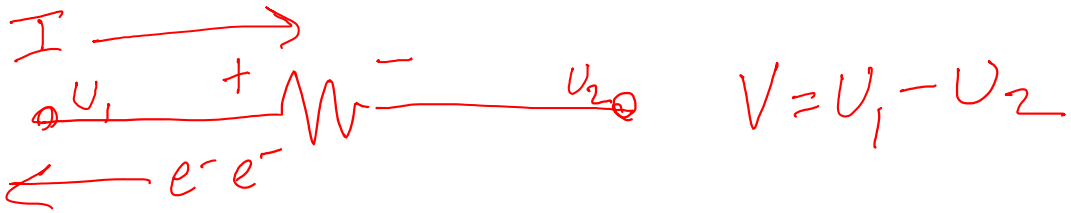
Admin

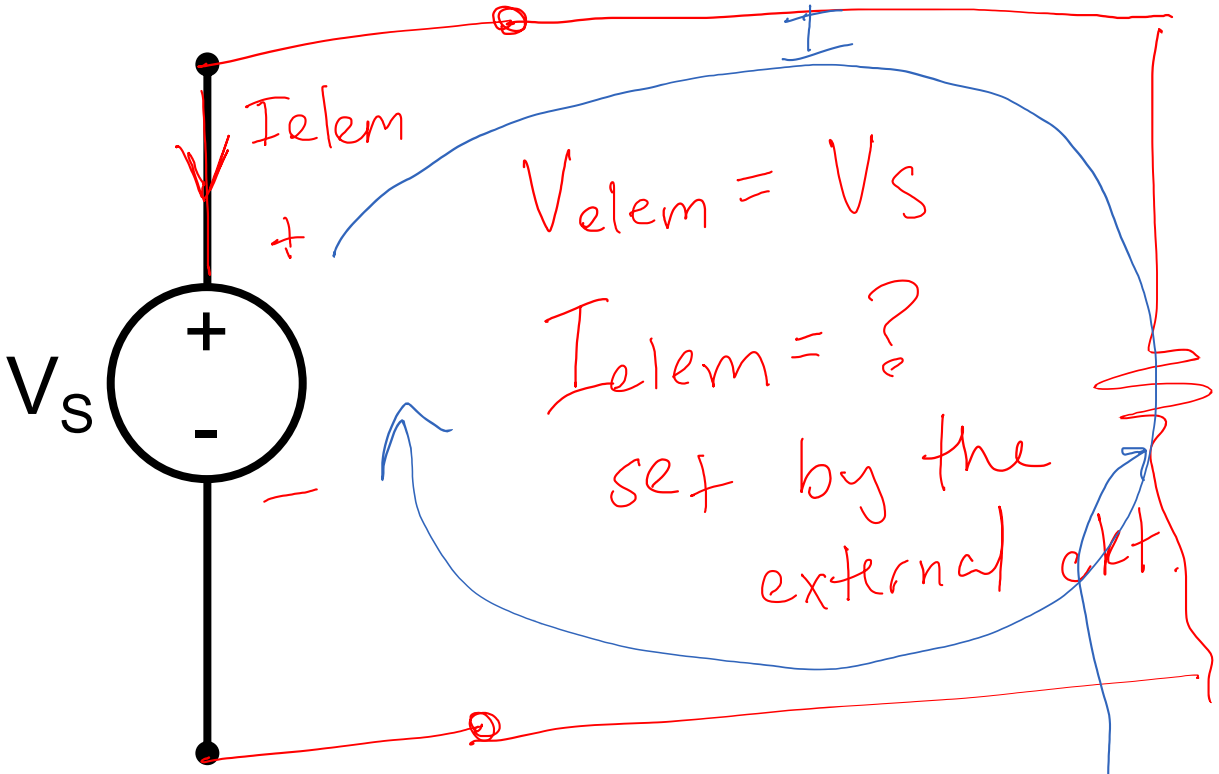
First Midterm Exam: Wednesday March 1, 7-9pm
Covers Module 1 Material up to 2/16 lecture.

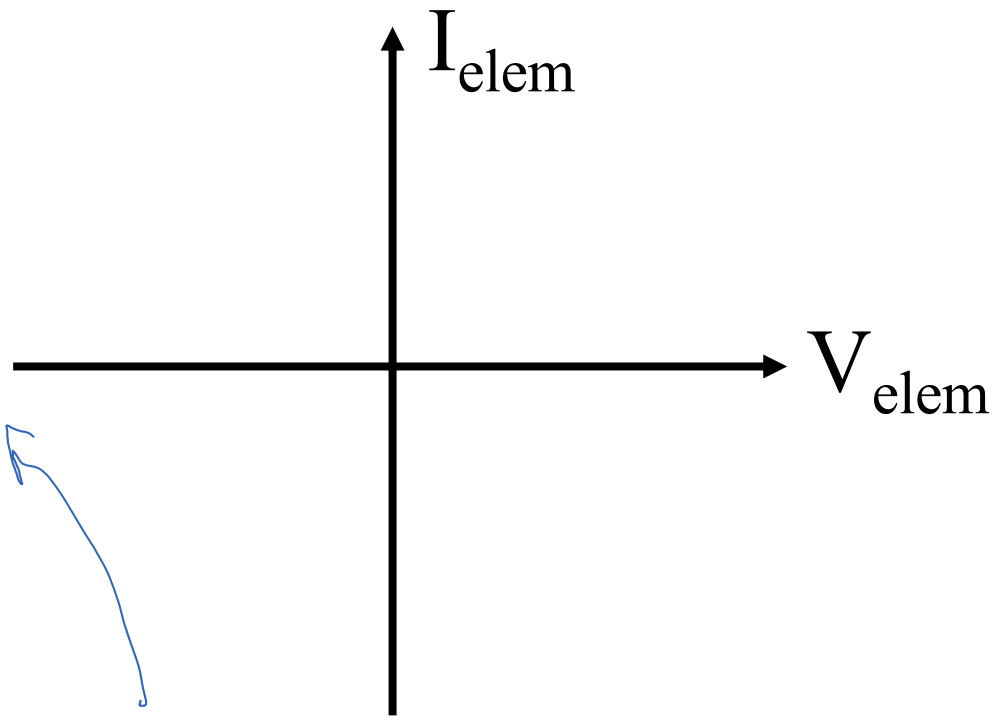
Things I shouldn't have to say…

Cheating

"Value Set By External Circuit"





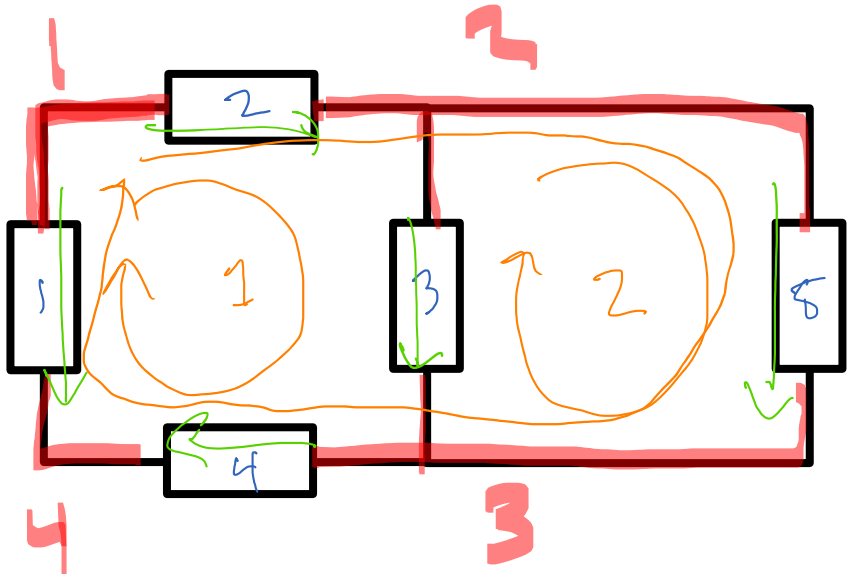


open $I_{elem} = 0$

Resitor I_{elem} = finite

externd circuit

Recap: Nodes, Branches, Loops



Elements? 5

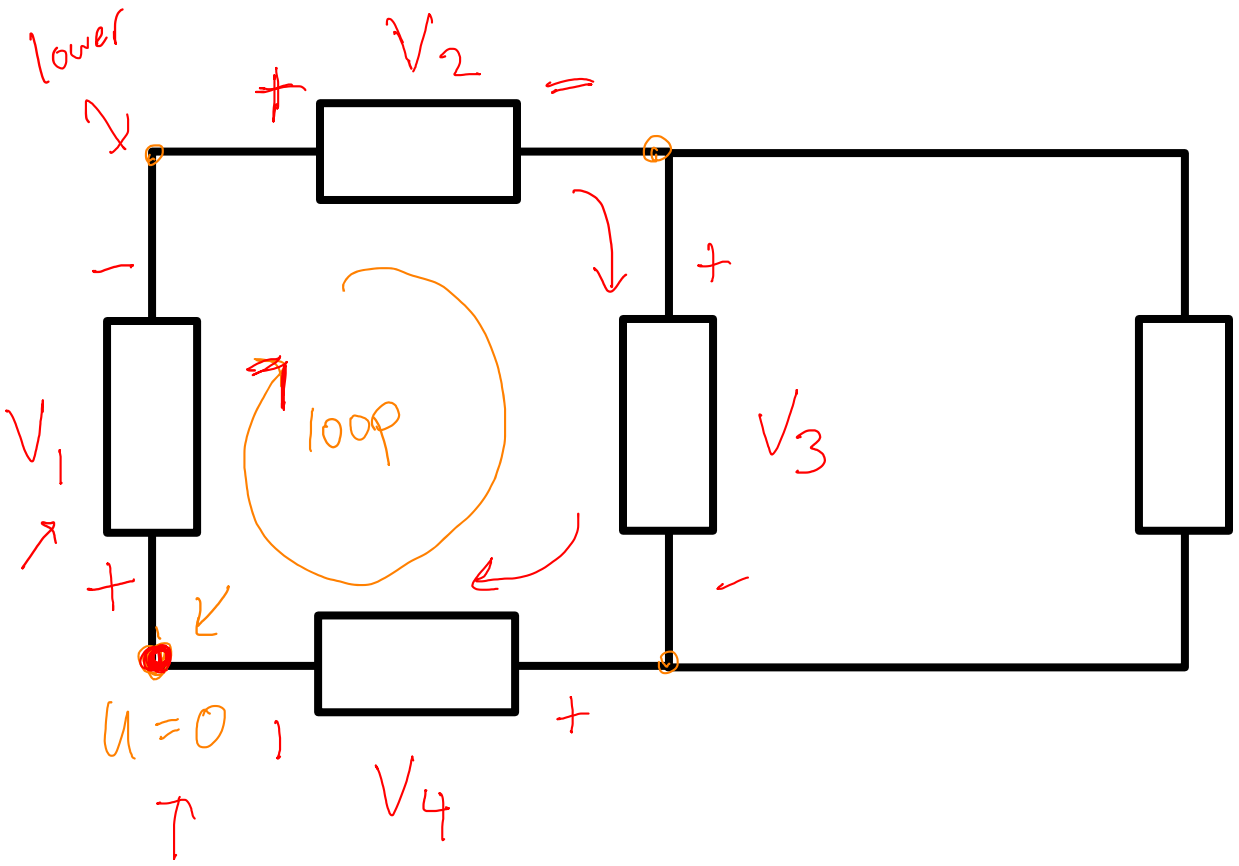
How many nodes in this circuit? 4

How many branches? 5

How many loops? 3

Rules for circuit analysis: Kirchoff's Voltage Law (KVL)

Sum of voltages across the elements in a loop equal zero



$$0 - V_1 - V_2 - V_3 - V_4 = 0$$

$$\Rightarrow V_1 + V_2 + V_3 + V_4 = 0$$

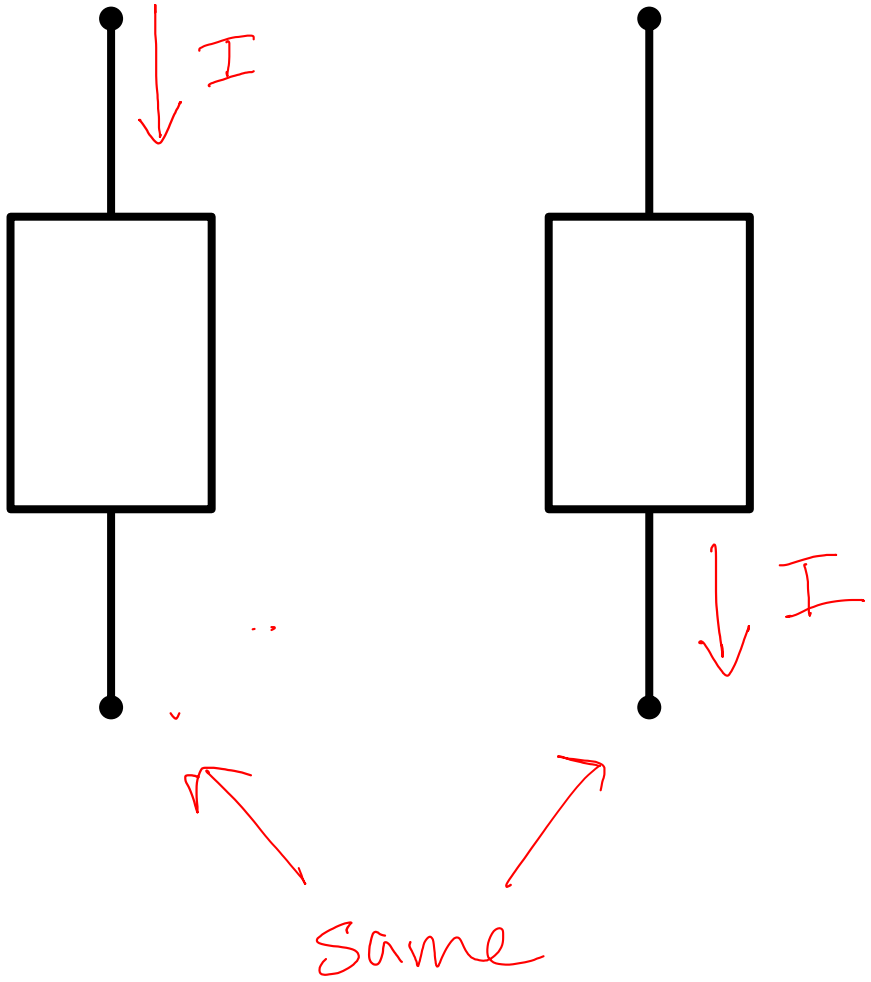
some can be positive

some can be negative

(mix of + & −)

Rules for circuit analysis: Kirchoff's Current Law (KCL) In-element

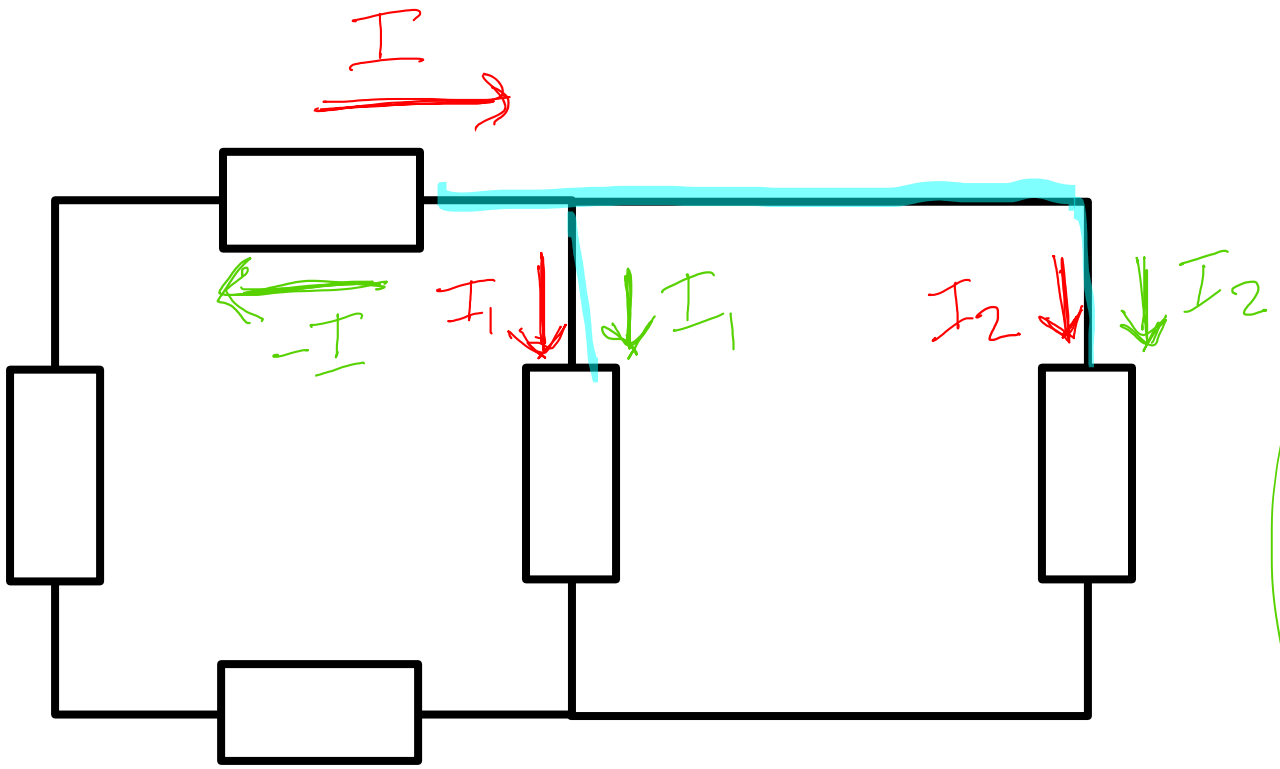
The current flowing into an element must equal the current flowing out



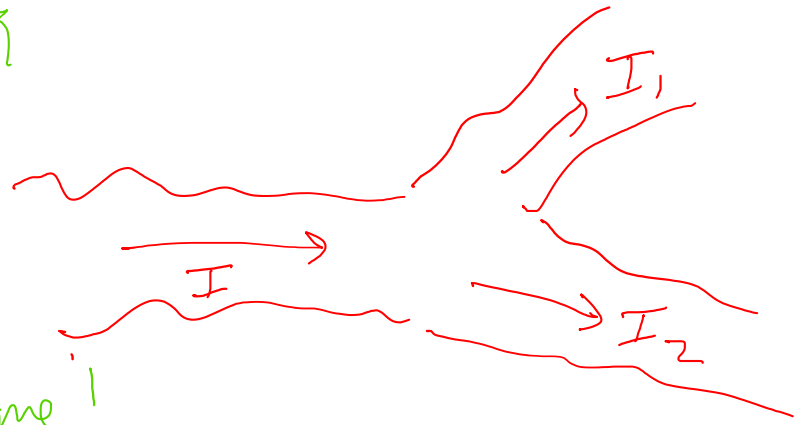
Rules for circuit analysis: Kirchoff's Current Law (KCL)

The current flowing into any node must equal the current flowing out

(same as: all currents flowing out of a node sum to 0)



$I = I_1 + I_2$

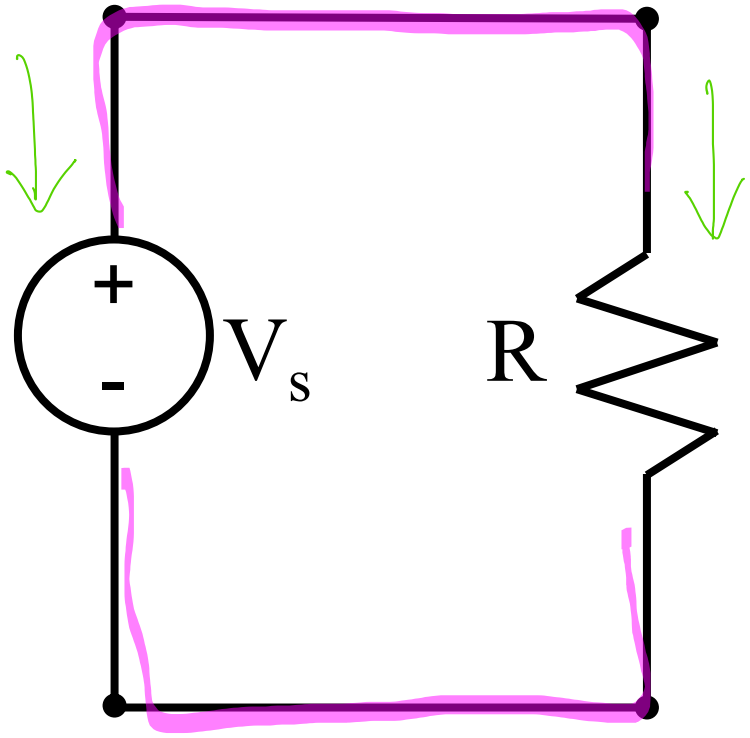


same!

$I_1 + I_2 - I = 0$

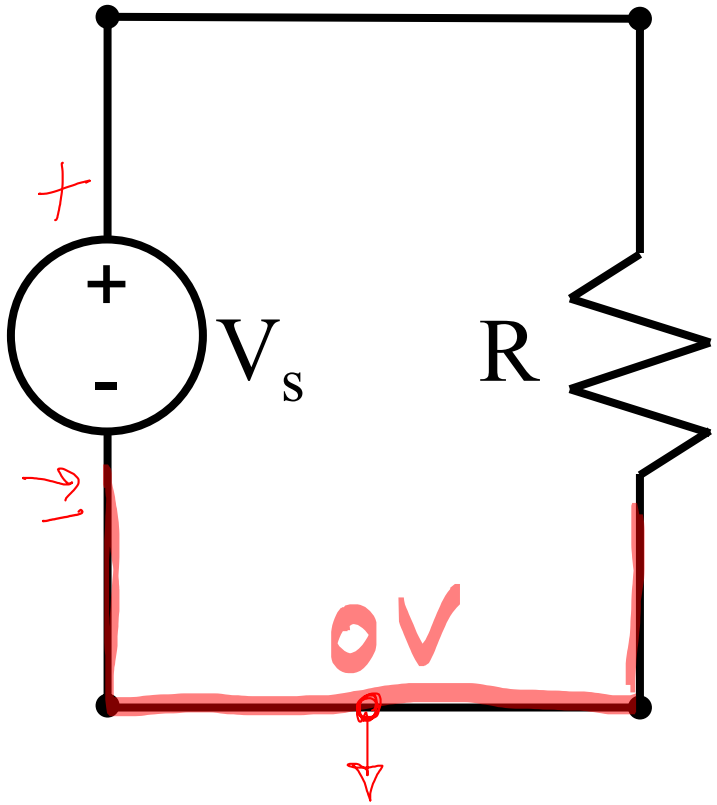
Example Circuit: Find all node voltages and branch currents

potentials



Circuit Analysis Algorithm: Step 1

Pick a reference node and label it as 0 potential (ground).
All voltages are measured relative to this node.



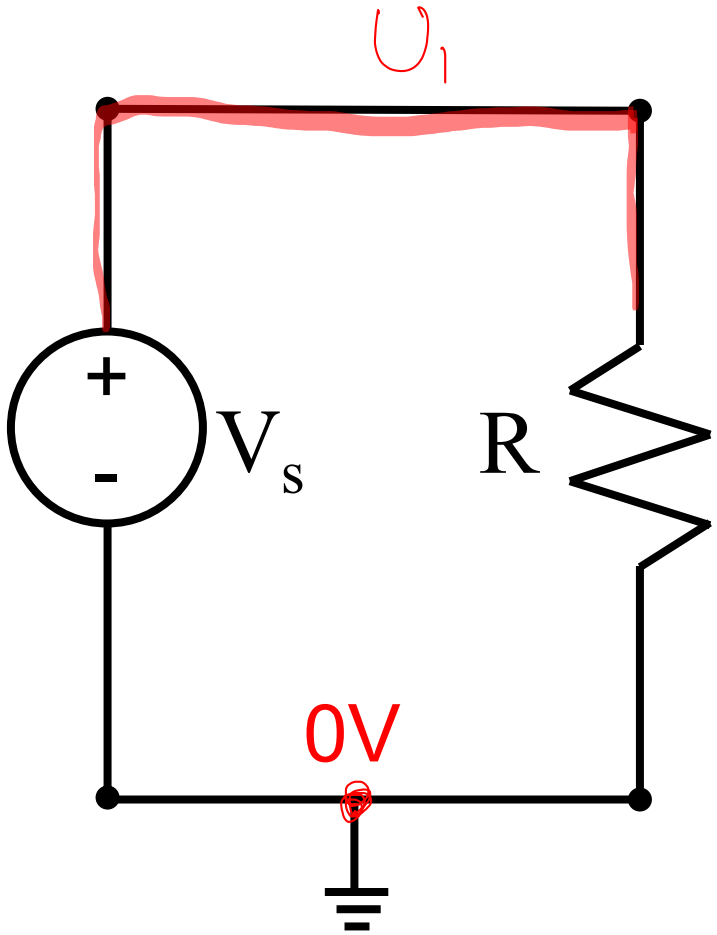
0V → "ground"

gnd

a good location is negative terminal of source (but not required)

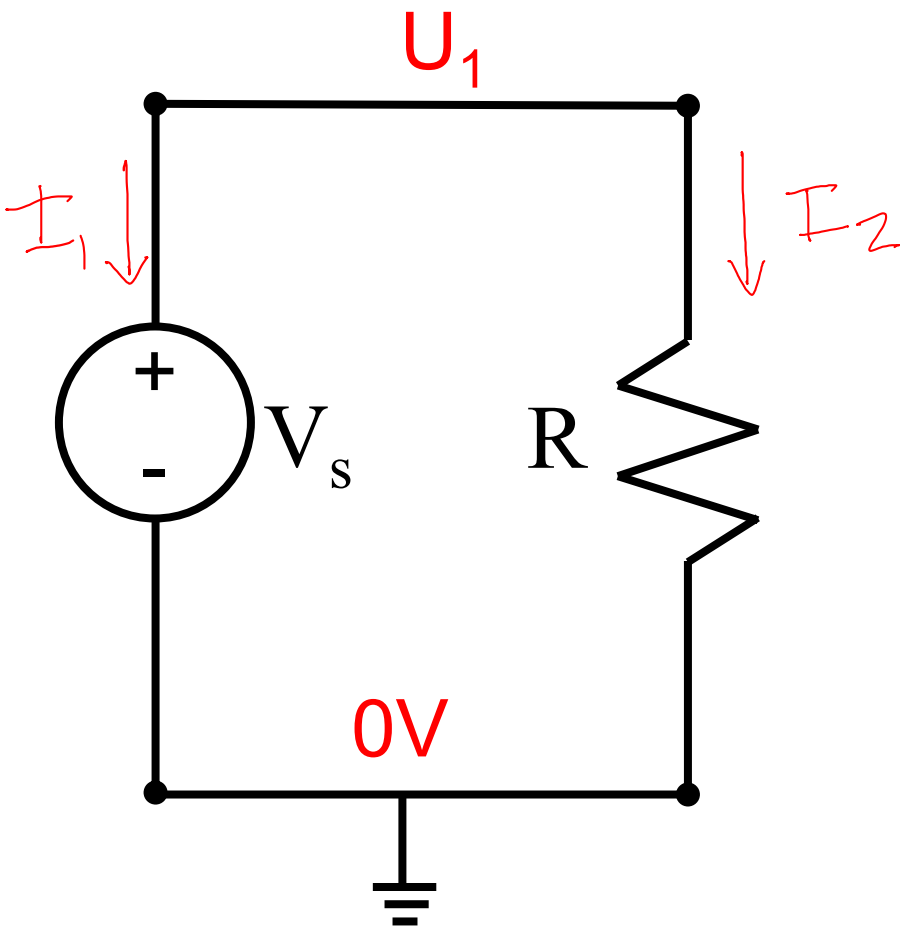
Circuit Analysis Algorithm: Step 2

Label all remaining nodes as potentials U_i
$[U_1 \ldots U_{N-1}]$



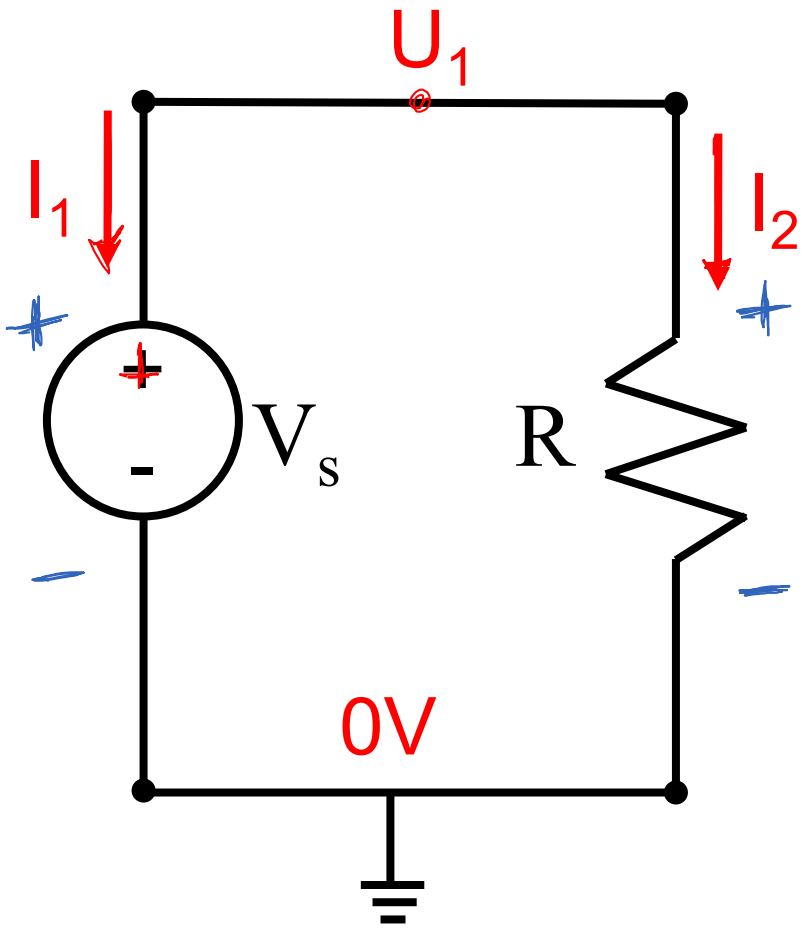
Circuit Analysis Algorithm: Step 3

Label all branch currents with I_i
$[I_1 \ldots I_k]$

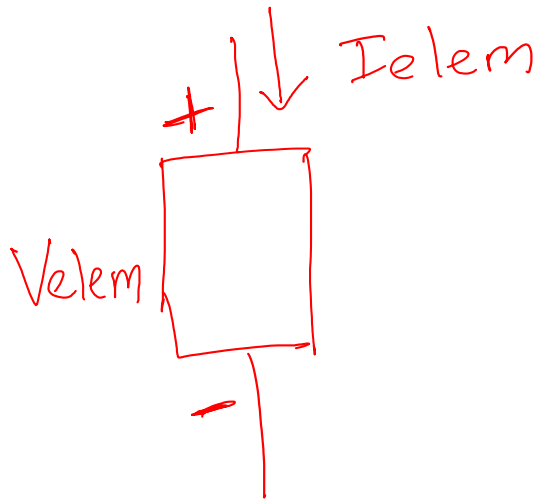


Circuit Analysis Algorithm: Step 4

Add signs + and – element voltages to each element following the passive sign convention

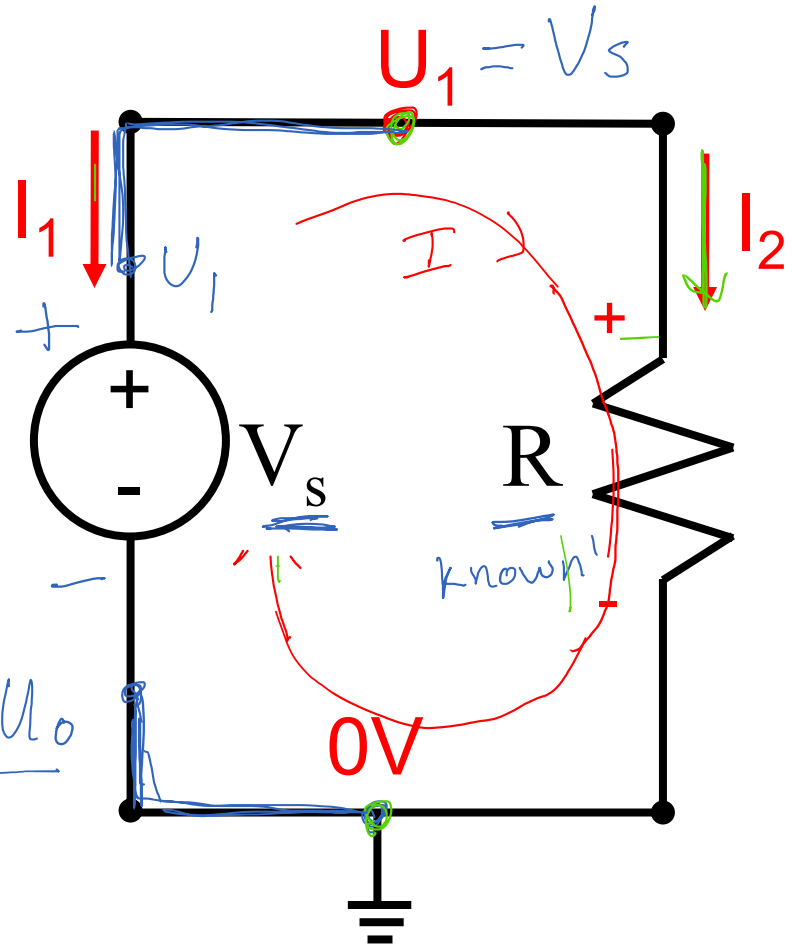


Passive sign convention: Positive current enters positive voltage terminal



Circuit Analysis Algorithm: Step 5

Identify unknowns and reduce using KVL/KCL



↳ all currents flowing out of anode = 0

I

unknowns: ~~U_1~~, I_1, I_2

KCL: $I_1 + I_2 = 0$ ←

$I_2 = -I_1 = I$ ←

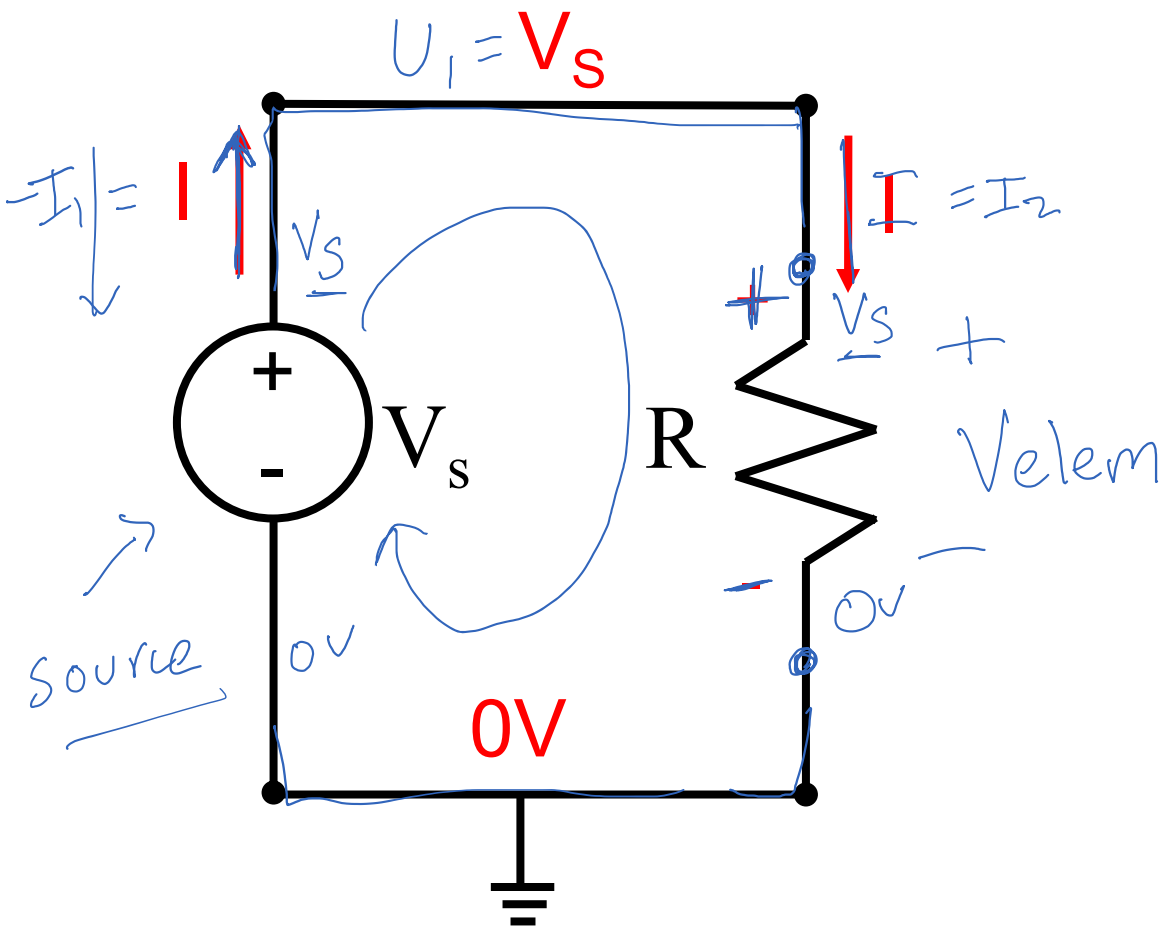
KVL: $V_S = U_1 - U_0$

$V_S = U_1 - 0$

$V_S = U_1$

Circuit Analysis Algorithm: Step 6

Identify remaining unknowns and set up a system of linear equations to solve using KVL/KCL/I-V equations



$V = IR$

$V_S - 0 = IR$ ← known!

$$I = \frac{V_S}{R}$$

Circuit Analysis Algorithm: Step 7 (if needed)

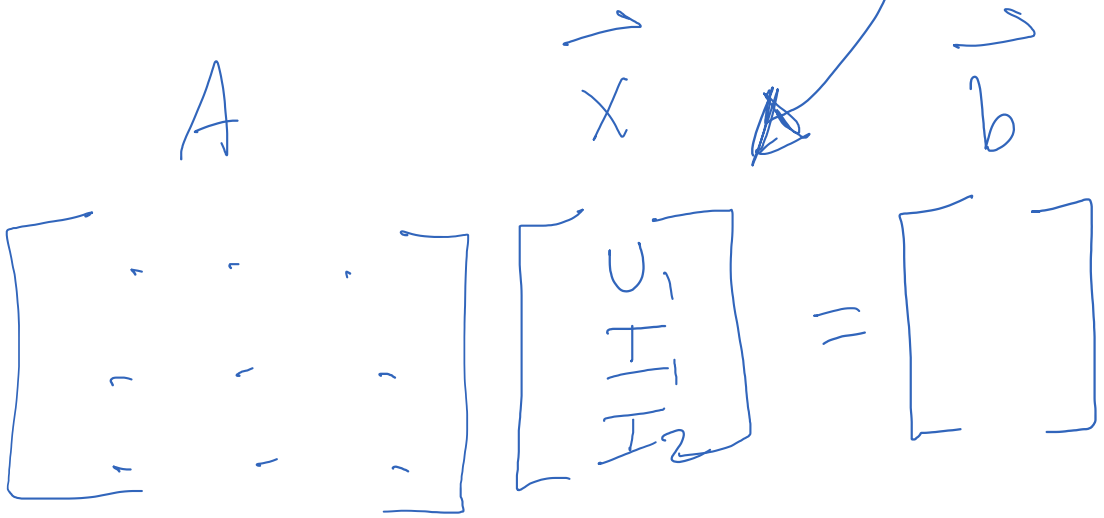
Is the system of equations complicated? Linear Algebra can help!

$$A\vec{x} = \vec{b}$$

$\vec{x}$ Unknowns (currents and potentials)

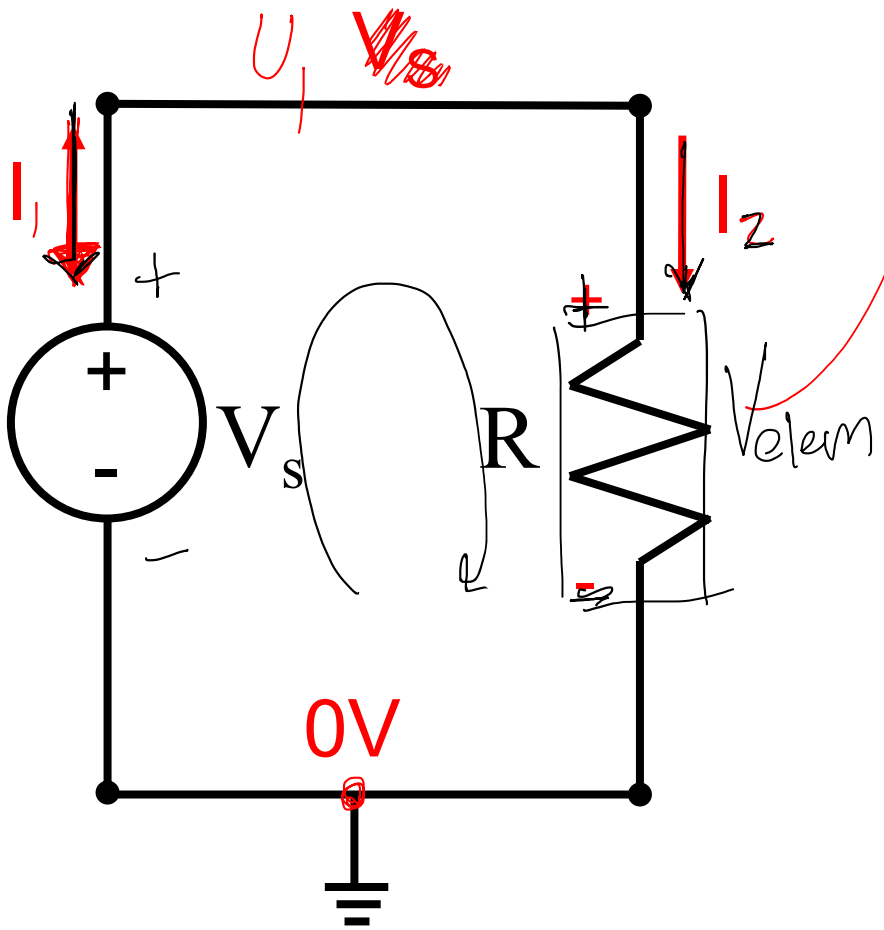
$\vec{b}$ Knowns/constants

A Knowns/constants



Circuit Analysis Algorithm: Step 7 (if needed)

Use KCL, KVL and V=IR to fill in A and $\vec{b}$



$V=IR$: $U_1 - 0 = I_2 R$

$U_1 - I_2 R = 0$

KCL: $I_1 + I_2 = 0$

KVL: $V_S = V_{elem} = U_1 - 0$

$V_S = U_1$

$U_1 = V_S$

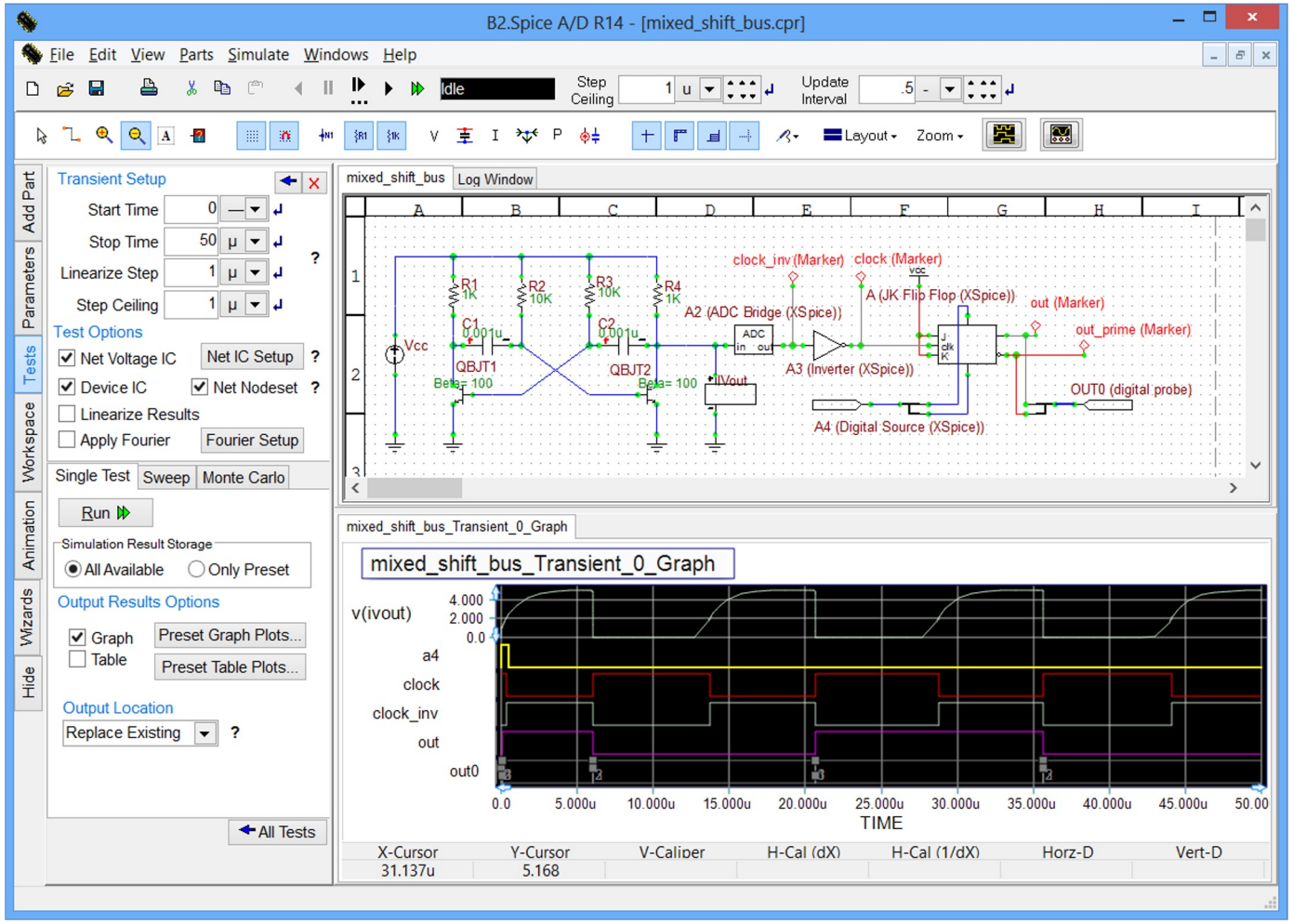
$$A\vec{x} = \vec{b}$$

$$\begin{bmatrix} 1 & 0 & -R \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} U_1 \\ I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ V_S \end{bmatrix}$$

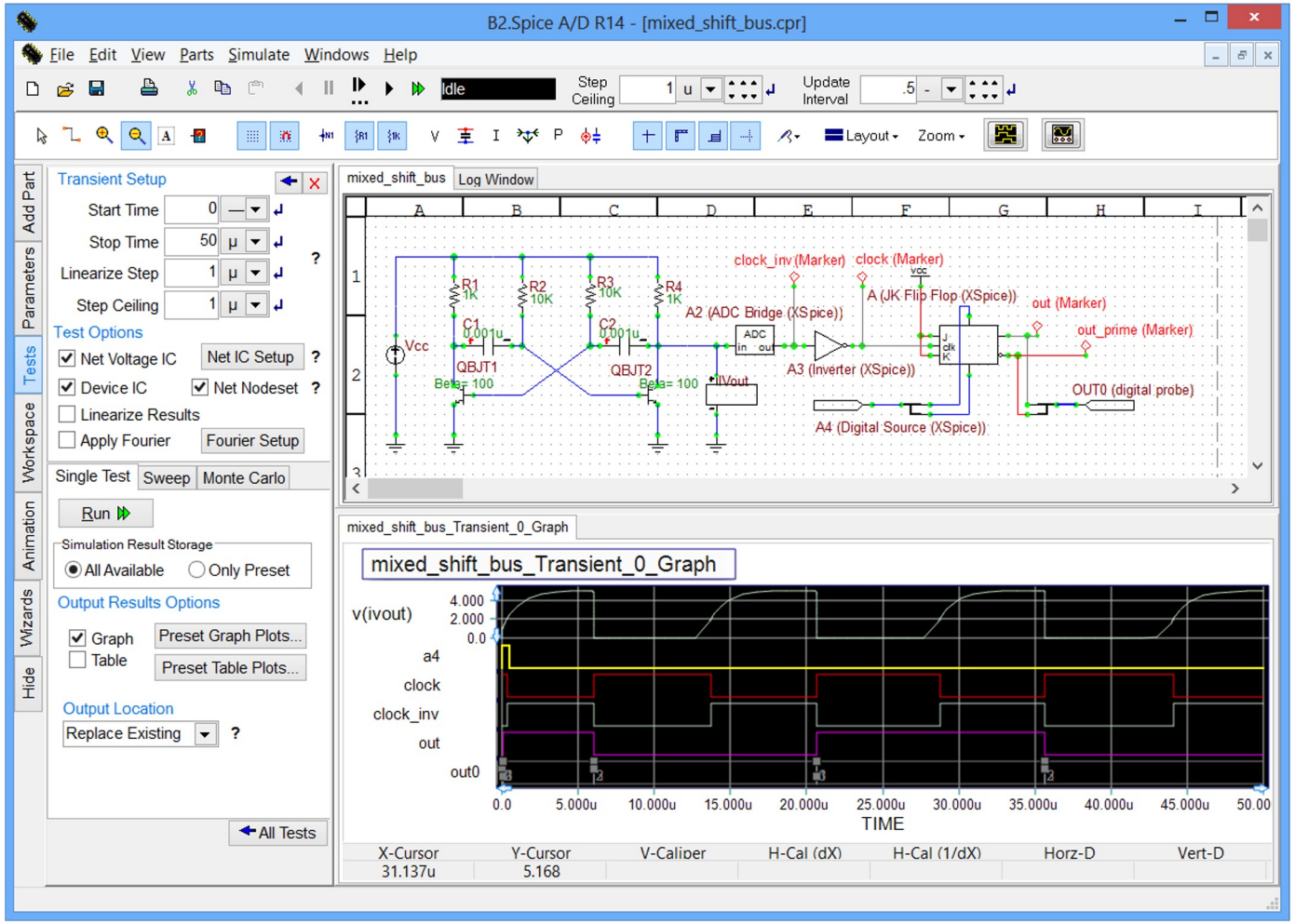
Electronic Design Automation (tool)

SPICE (Simulation Program with Integrated Circuit Emphasis): started as a student project at Berkeley!

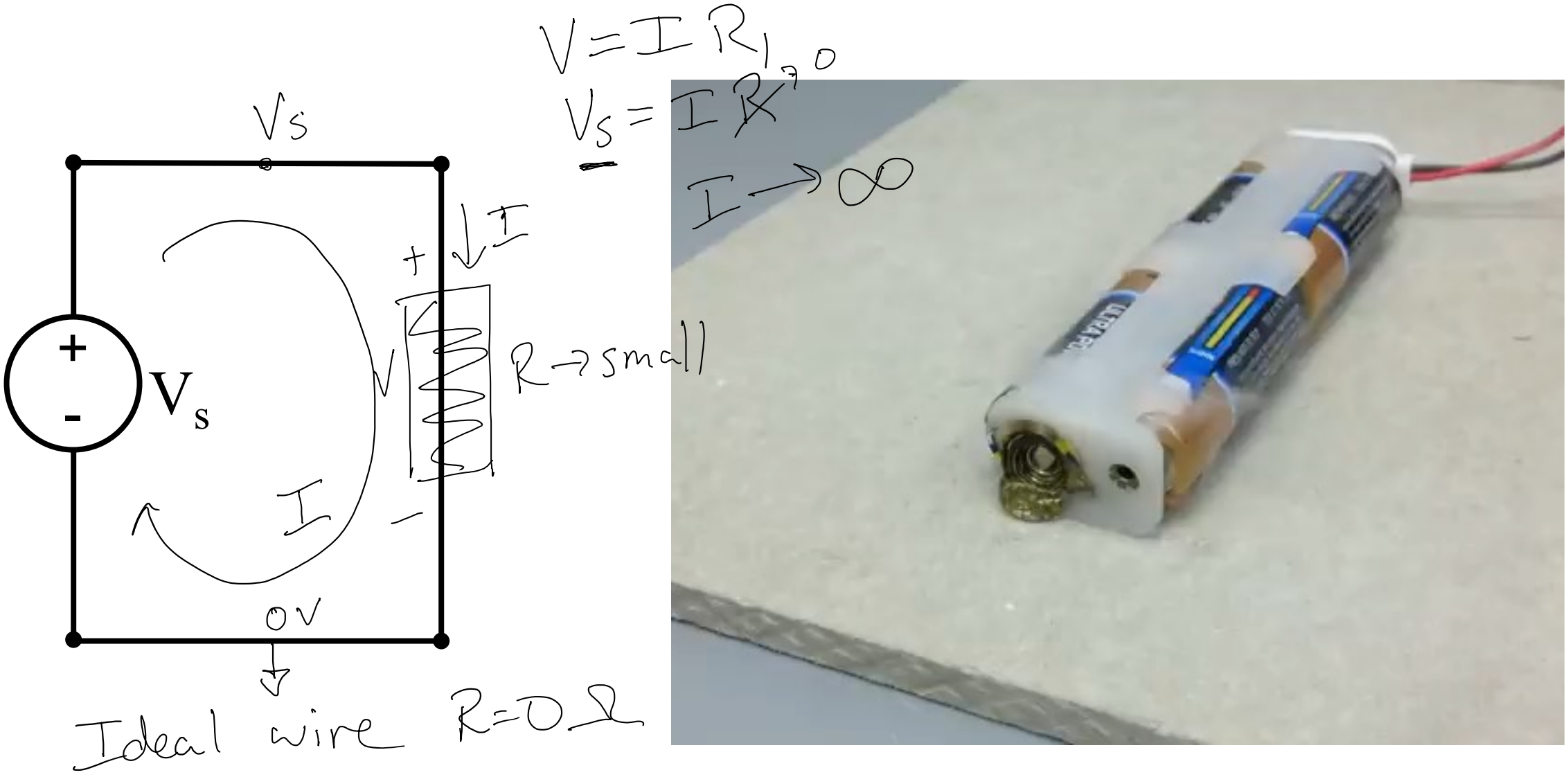
Now the basis for open-source electronic circuit simulation, to design and model device characteristics and check circuit boards



Electronic Design Automation (tool)

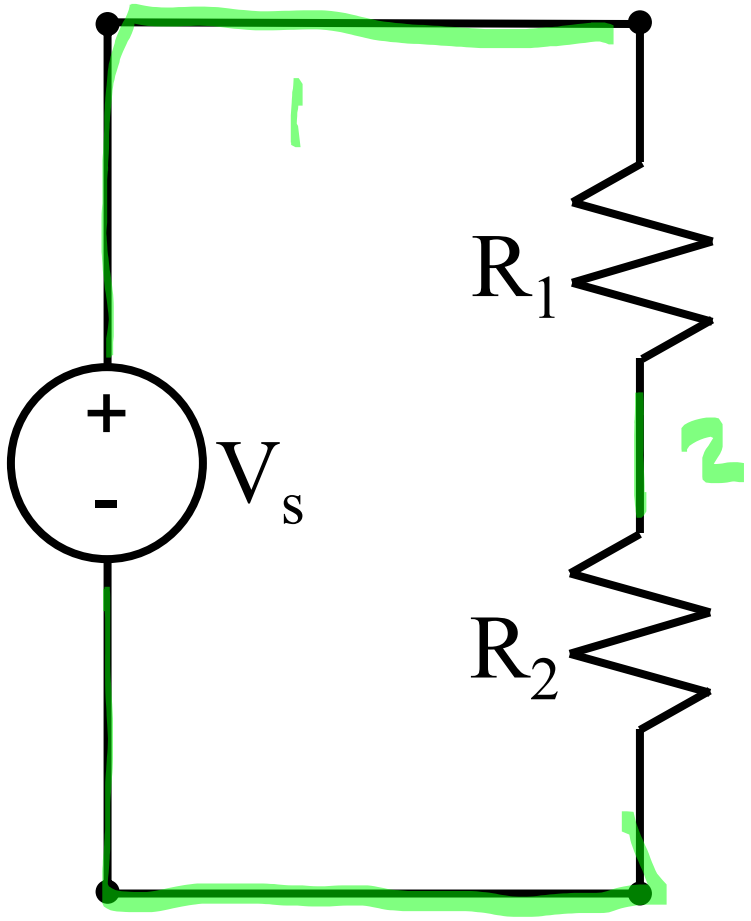


What Happens When You Short A Voltage Source?



Simplifying Circuit Analysis: The Voltage Divider

Find all node voltages and branch currents



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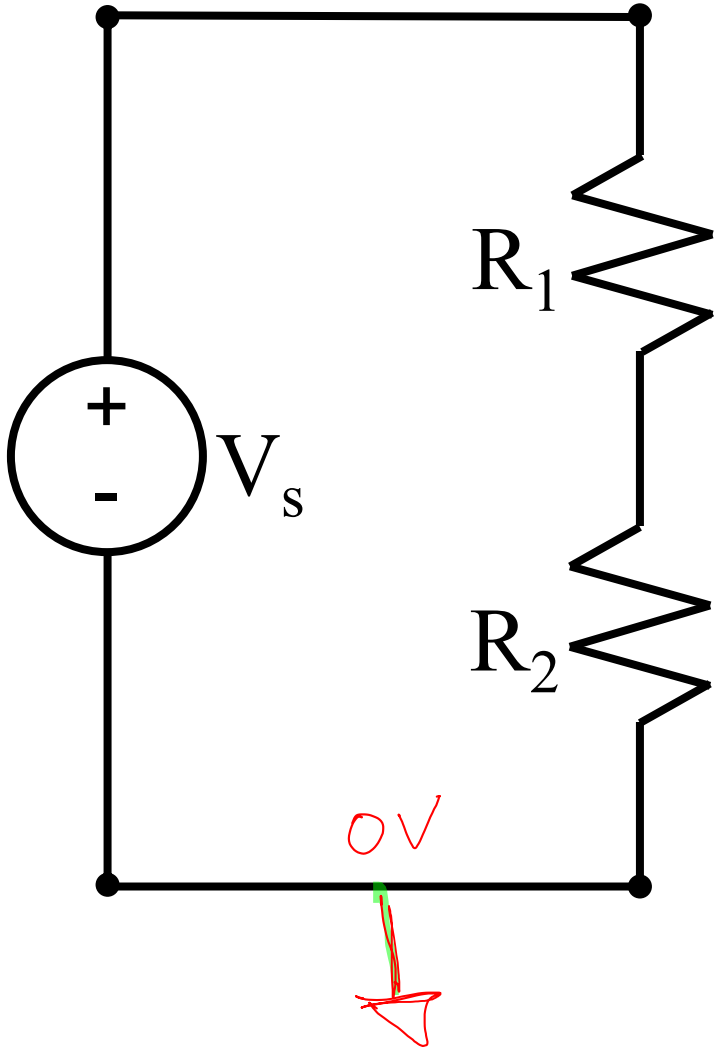
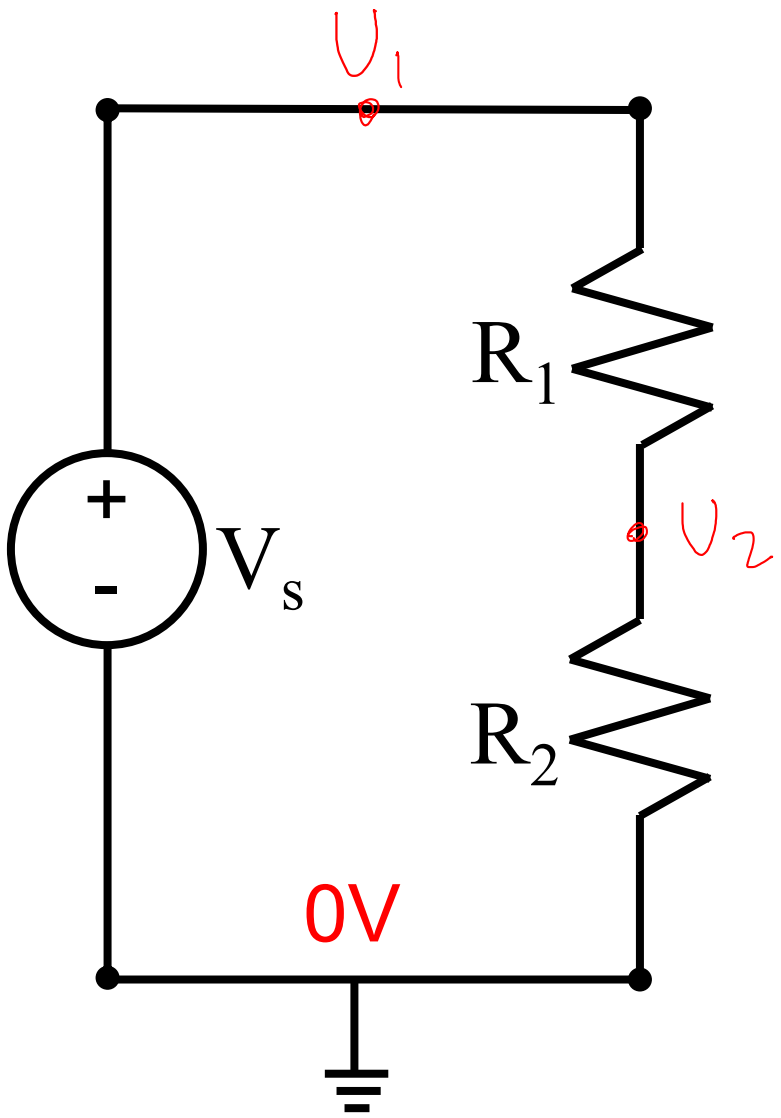


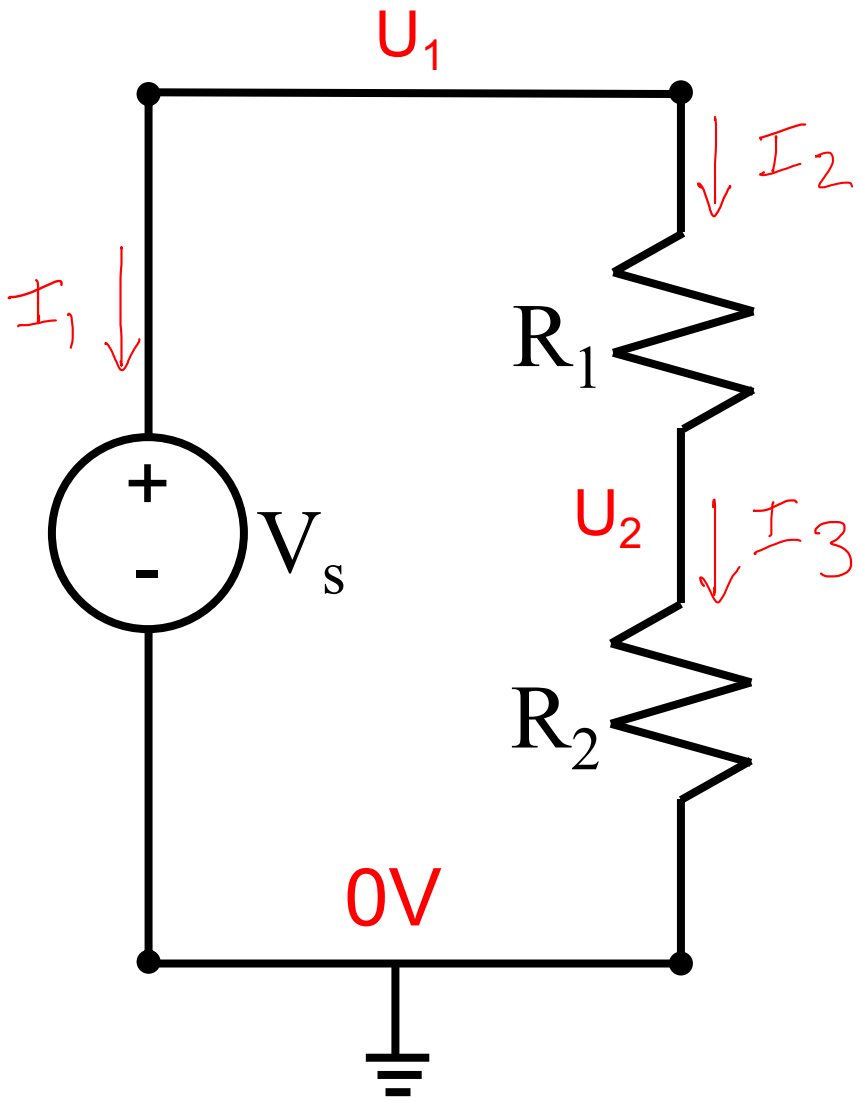
Circuit Analysis Algorithm: Step 2

Label all remaining nodes as potentials U_i $[U_1 \ldots U_{N-1}]$



Circuit Analysis Algorithm: Step 3

Label all branch currents with I_i $[I_1 \ldots I_k]$



Circuit Analysis Algorithm: Step 4

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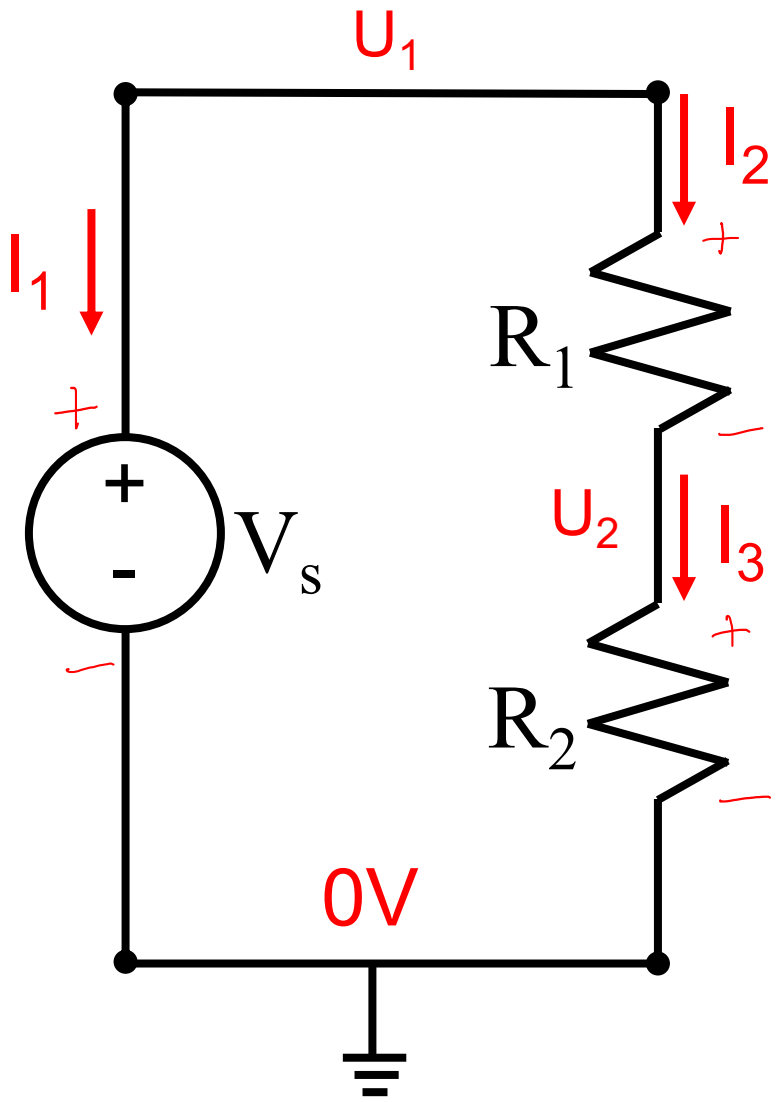

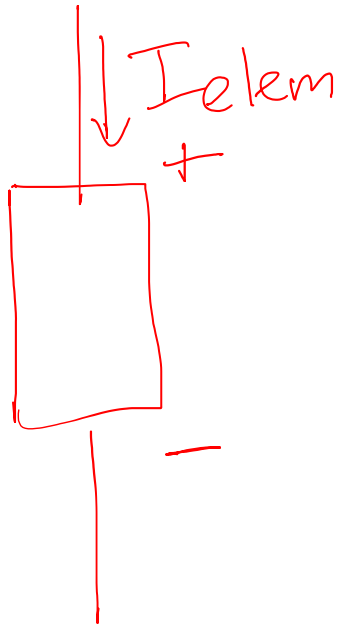

Circuit Analysis Algorithm: Step 5

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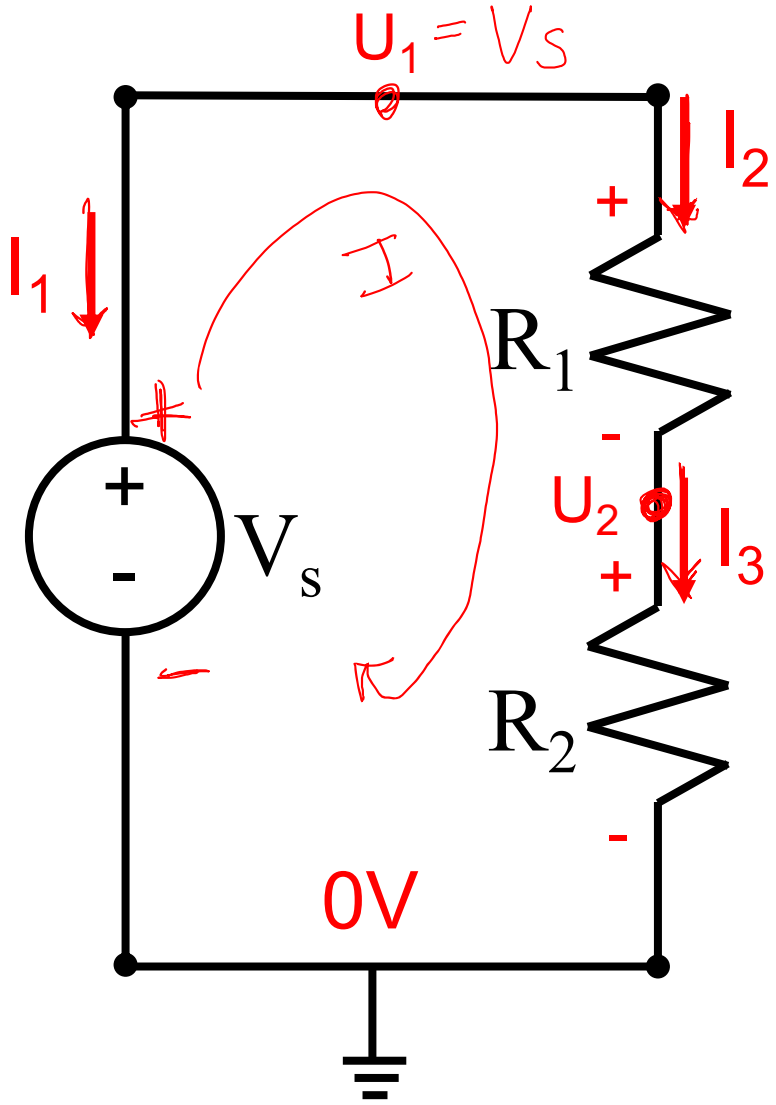


Unknowns: ~~U_1~~, U_2, I_1, I_2, I_3

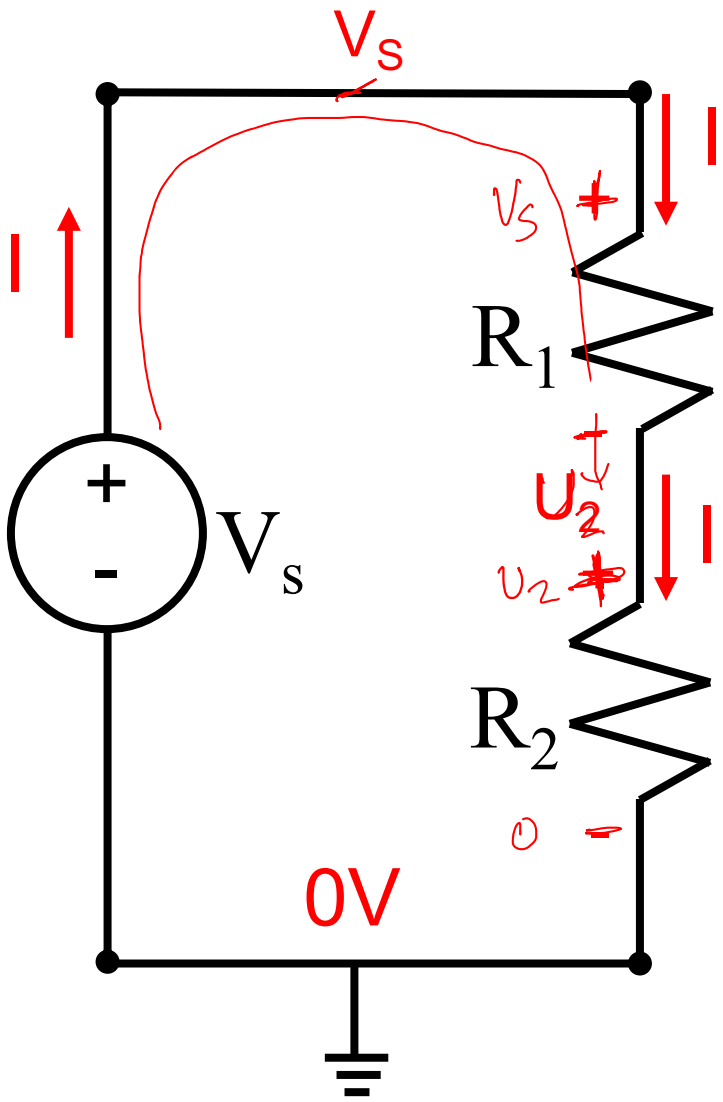
$V_S = U_1 - 0$ $\quad V_S = V_1$

KCL: $I_1 + I_2 = 0$

$I = I_2 = -I_1 = I_3$

Circuit Analysis Algorithm: Step 6

Identify remaining unknowns and set up a system of linear equations to solve using KVL/KCL/I-V equations



Unknowns: I, U_2

ohm's law: $V = IR_1$

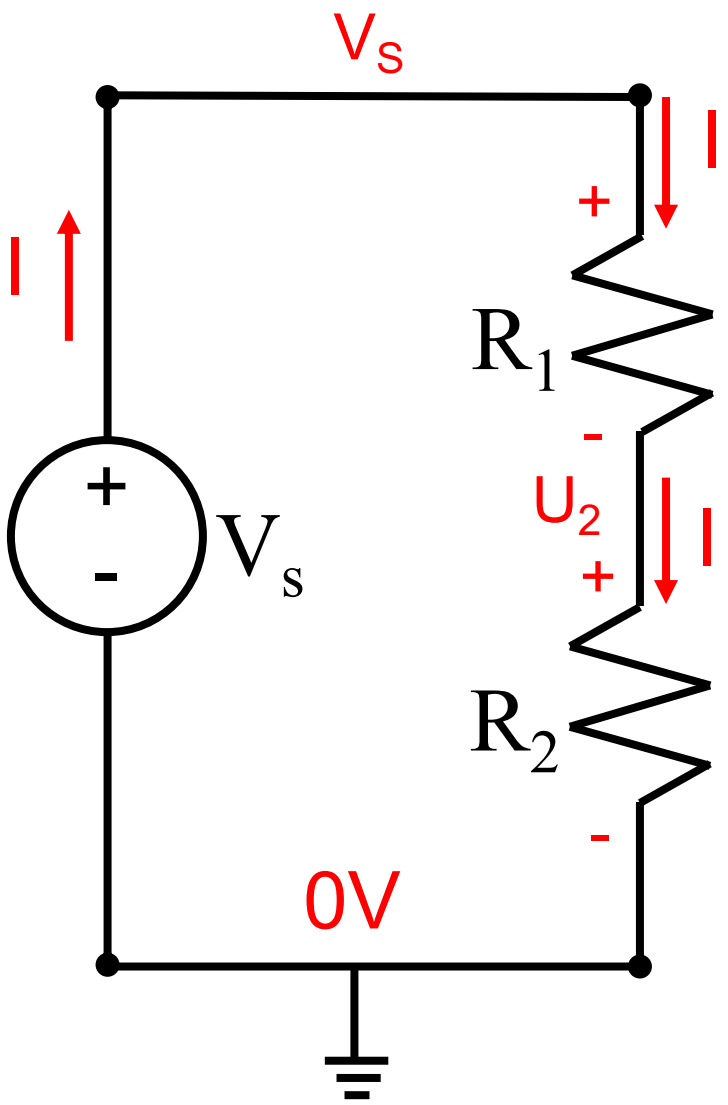
$V_S - U_2 = IR_1$

$* \; IR_1 + U_2 = V_S$

$U_2 - 0 = IR_2$

$* \; IR_2 - U_2 = 0$

Circuit Analysis Algorithm: Step 7 (if needed)



Is the system of equations complicated? Linear Algebra can help! $A\vec{x} = \vec{b}$

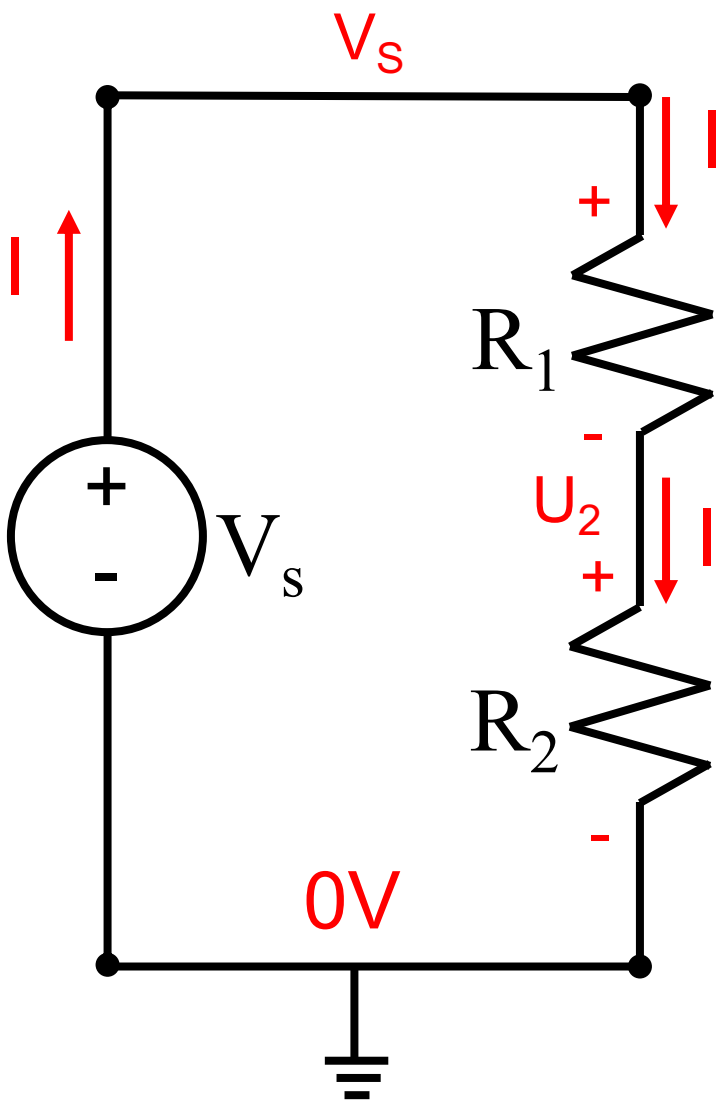
$\rightarrow I R_1 + U_2 = V_S$

$\rightarrow I R_2 - U_2 = 0$

$$\begin{bmatrix} R_1 & 1 \\ R_2 & -1 \end{bmatrix} \begin{bmatrix} I \\ U_2 \end{bmatrix} = \begin{bmatrix} V_S \\ 0 \end{bmatrix}$$

($\vec{x}$)

Voltage Divider Summary



$$I = \frac{V_S}{R_1 + R_2}$$

$$U_2 = \frac{V_S R_2}{R_1 + R_2}$$

Voltage Divider Analogy