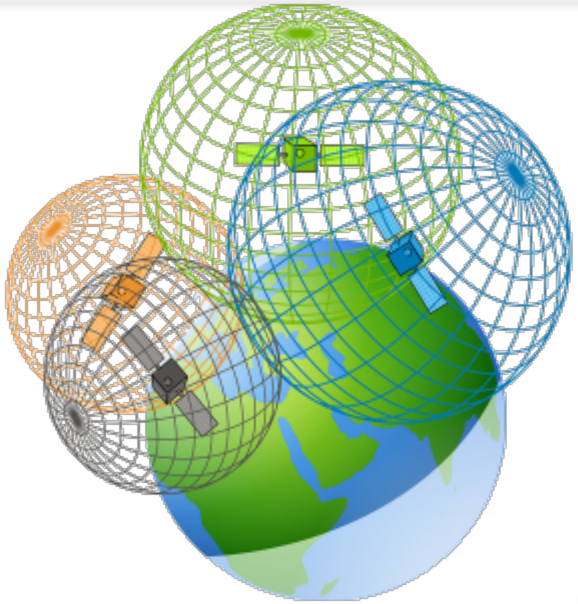


Welcome to EECS 16A!

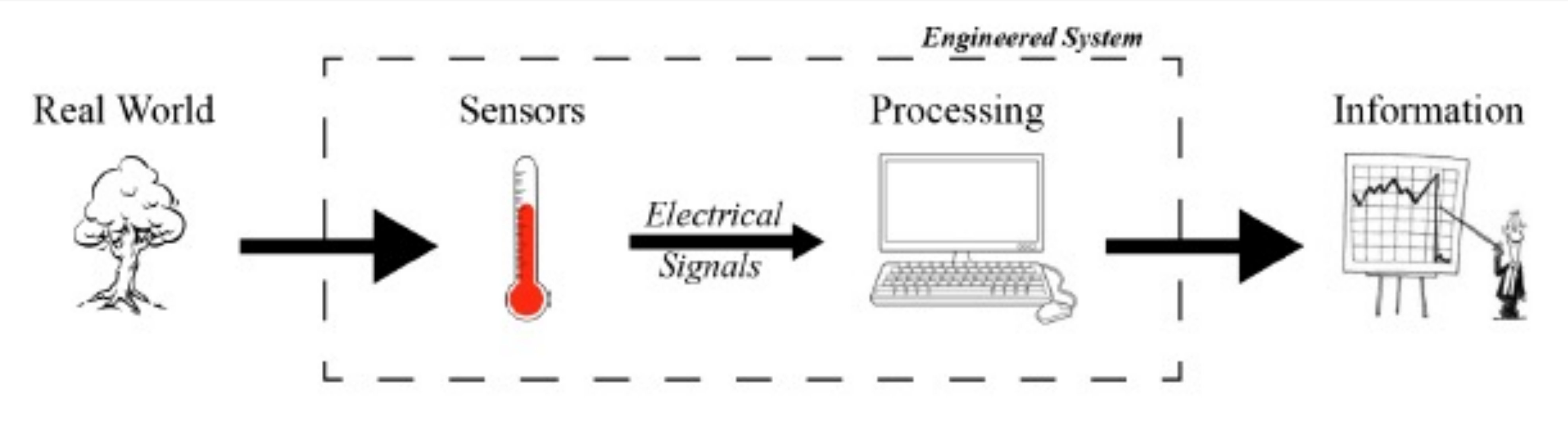
Designing Information Devices and Systems I

Ana Claudia Arias and Miki Lustig

Fall 2021

Module 2
Lecture 1
Introduction to Circuit Analysis
(Note 11)

Designing Information Devices and Systems



Module 2 – More tools to build systems

Analog World | Sensor | Processing | Actuation

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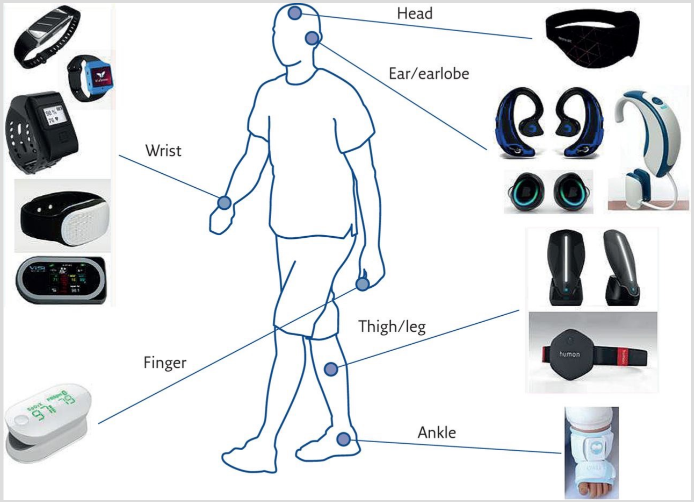
Module 2 – More tools to build systems

Analog World

Sensor

Processing

Actuation



Module 2 – More tools to build systems

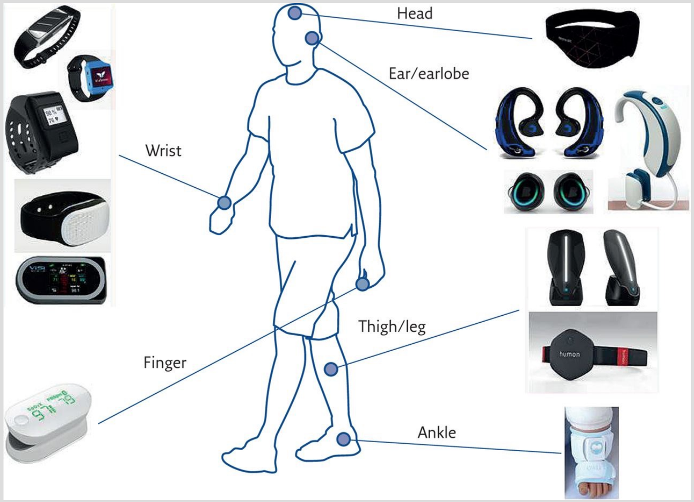
Analog World

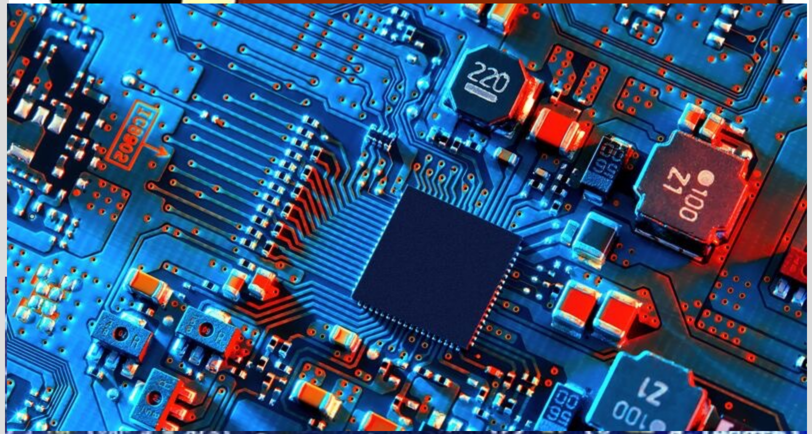
Sensor

Processing

Actuation

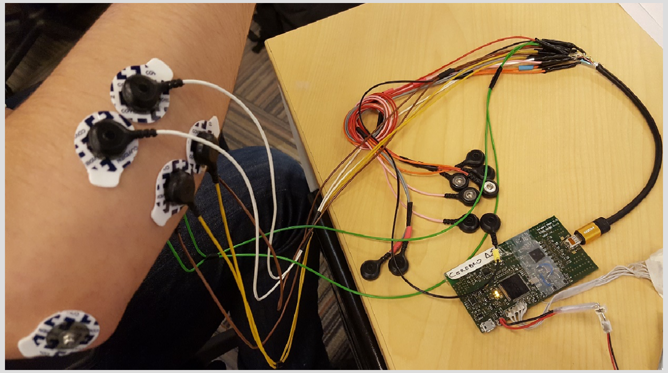
16B





System Example - Electromyography

- ✓ Monitors muscle activity
- ✓ Used in gesture recognition
- ✓ Impact in rehabilitation



- X Bulky electrodes
- X Poor accuracy – low resolution
- X Computation performed on external devices

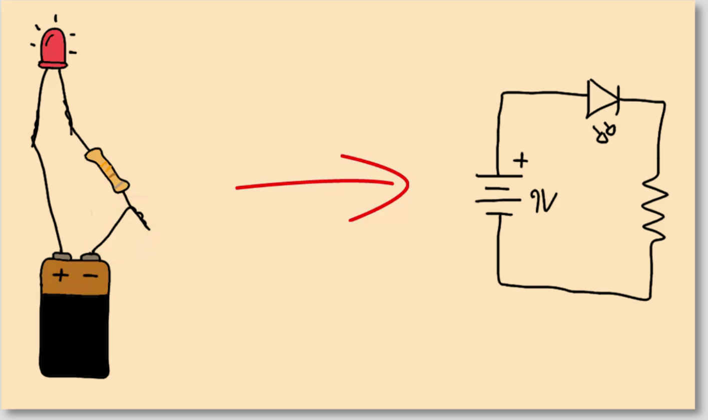
System Example - Electromyography

Berkeley
UNIVERSITY OF CALIFORNIA

NOVACENTRIX

In Module 2 we will learn how to analyze circuits

We need to be able to go from a real-world circuit, to a circuit model, and vice versa.



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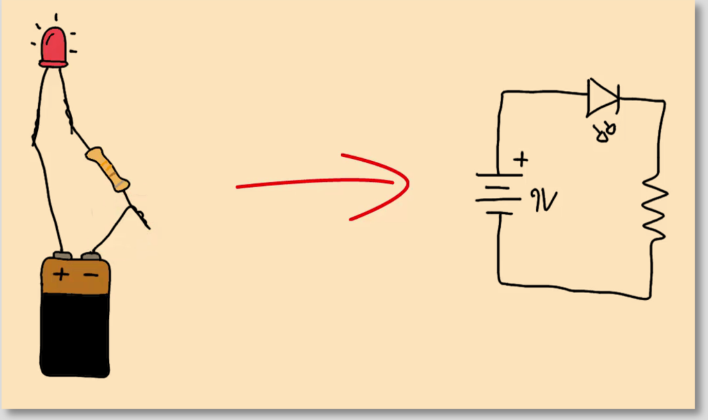
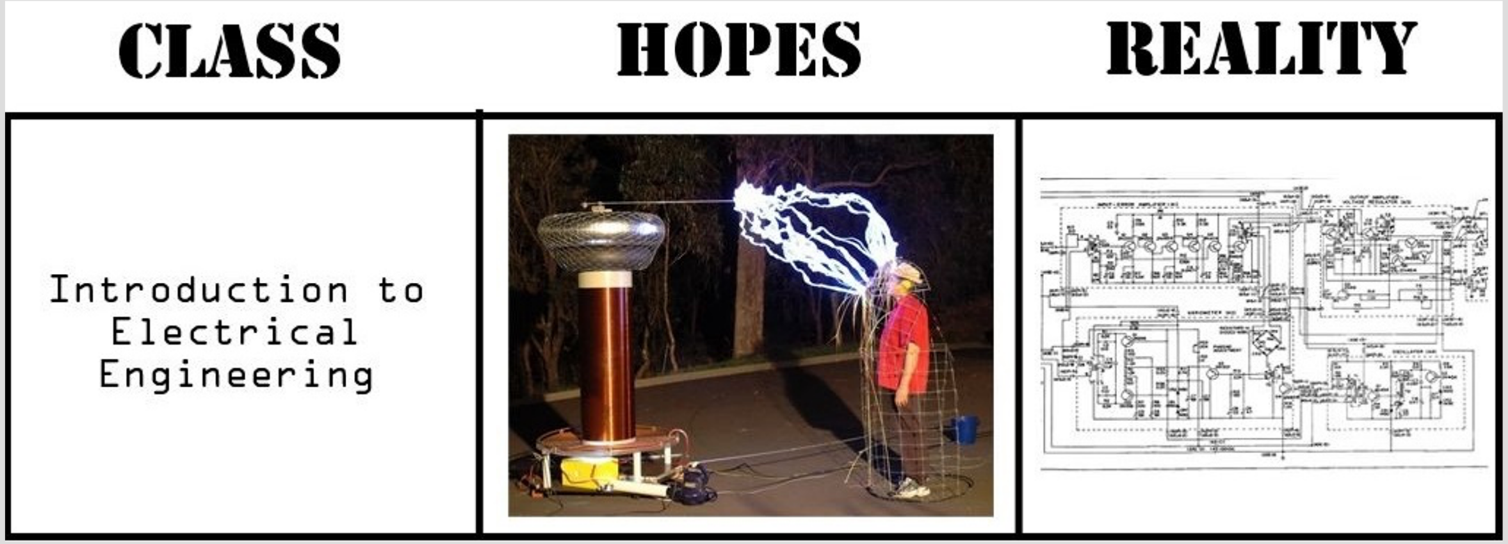
We need to be able to go from a real-world circuit, to a circuit model, and vice versa.





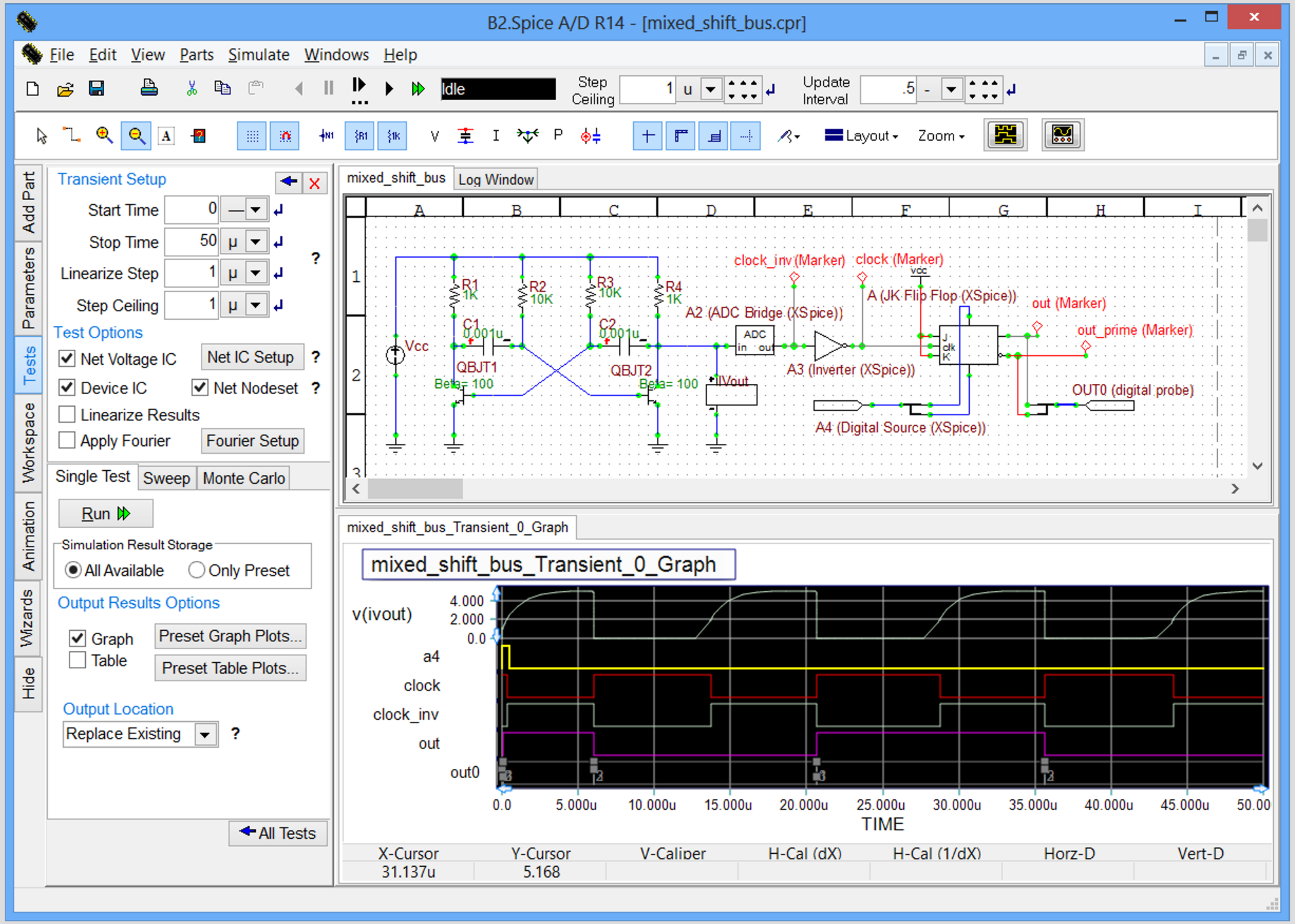
Then we need to know how to solve the model…

Note: the tool used by computers to analyze circuits is *linear algebra*!

Electrical Circuit Analysis Algorithm (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



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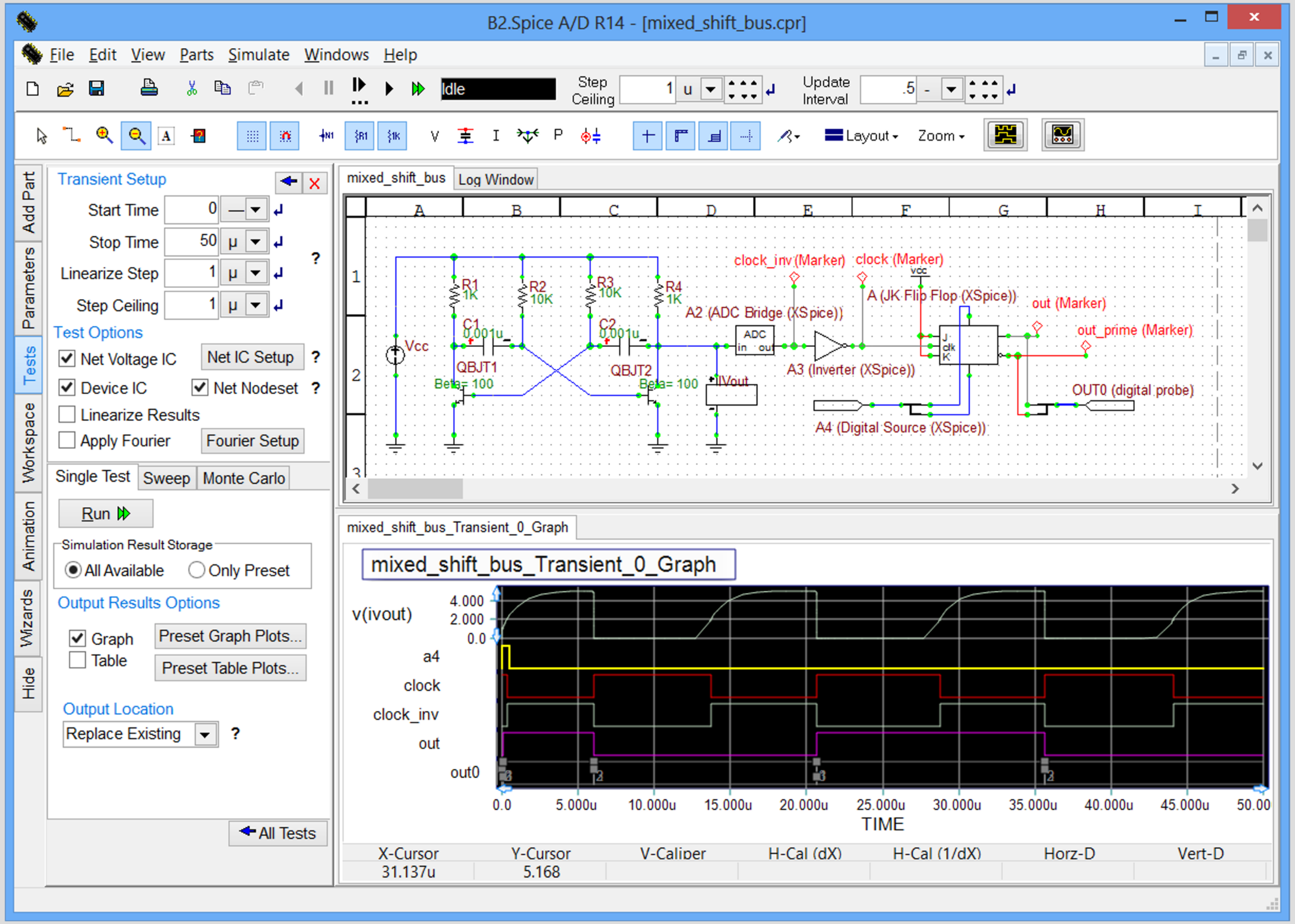
Prof. Alberto L. Sangiovanni-Vincentelli

Electrical Circuit Analysis Algorithm (tool)



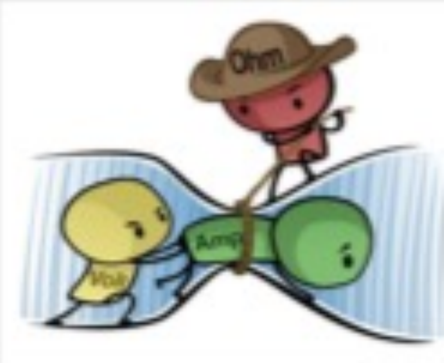
Definitions needed to analyze a circuit :quantities

Quantities	Analytical Symbol	Units
Current	I	Amperes [A]
Voltage	V	Volts [V]
Resistance	R	Ohms [Ω]

I ⇒ flows through an element

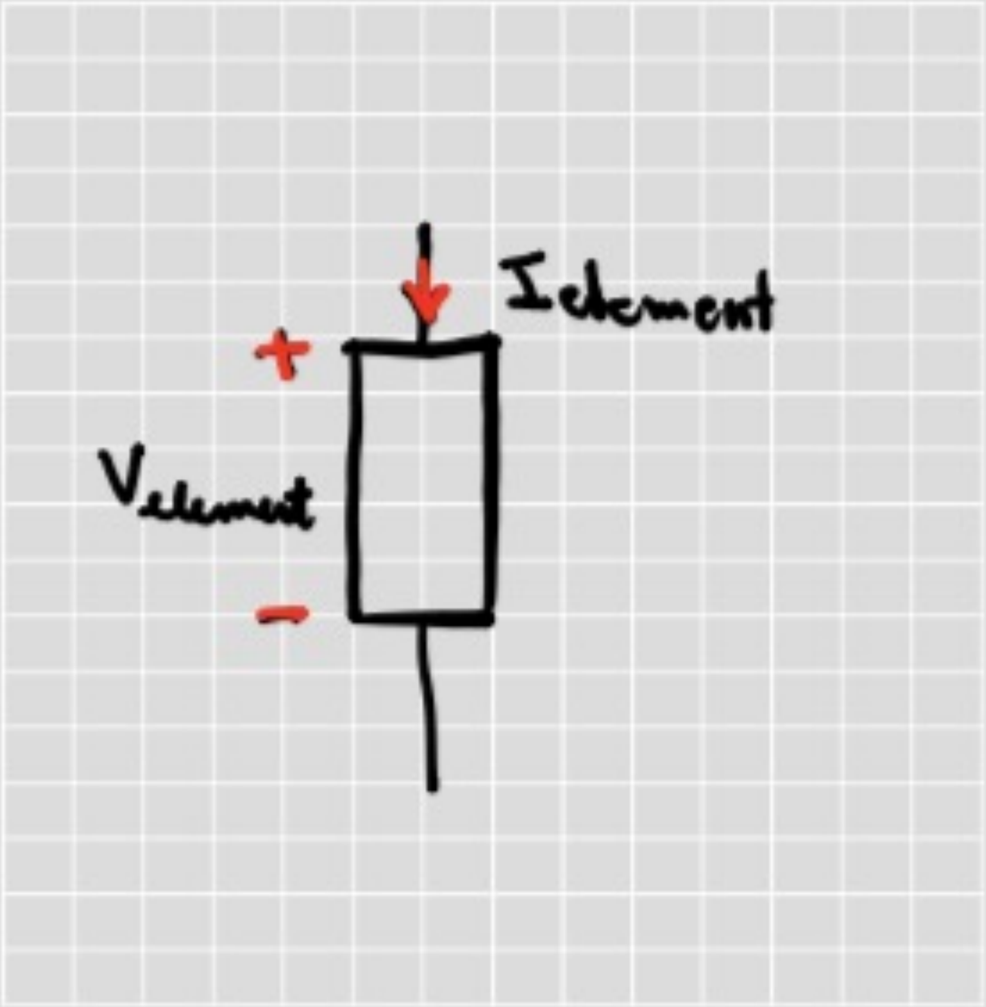
V ⇒ applied across an element

R ⇒ opposition to current flow

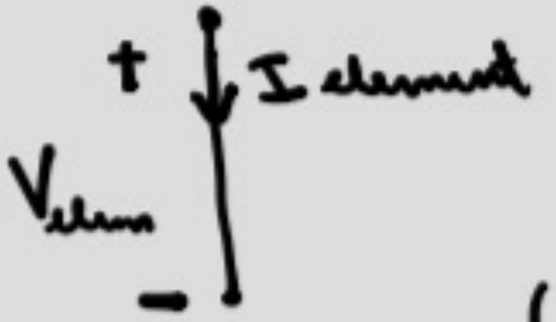


Definitions needed to analyze a circuit : Circuit Diagram

Collection of elements, where each element has some voltage across it and some current through it



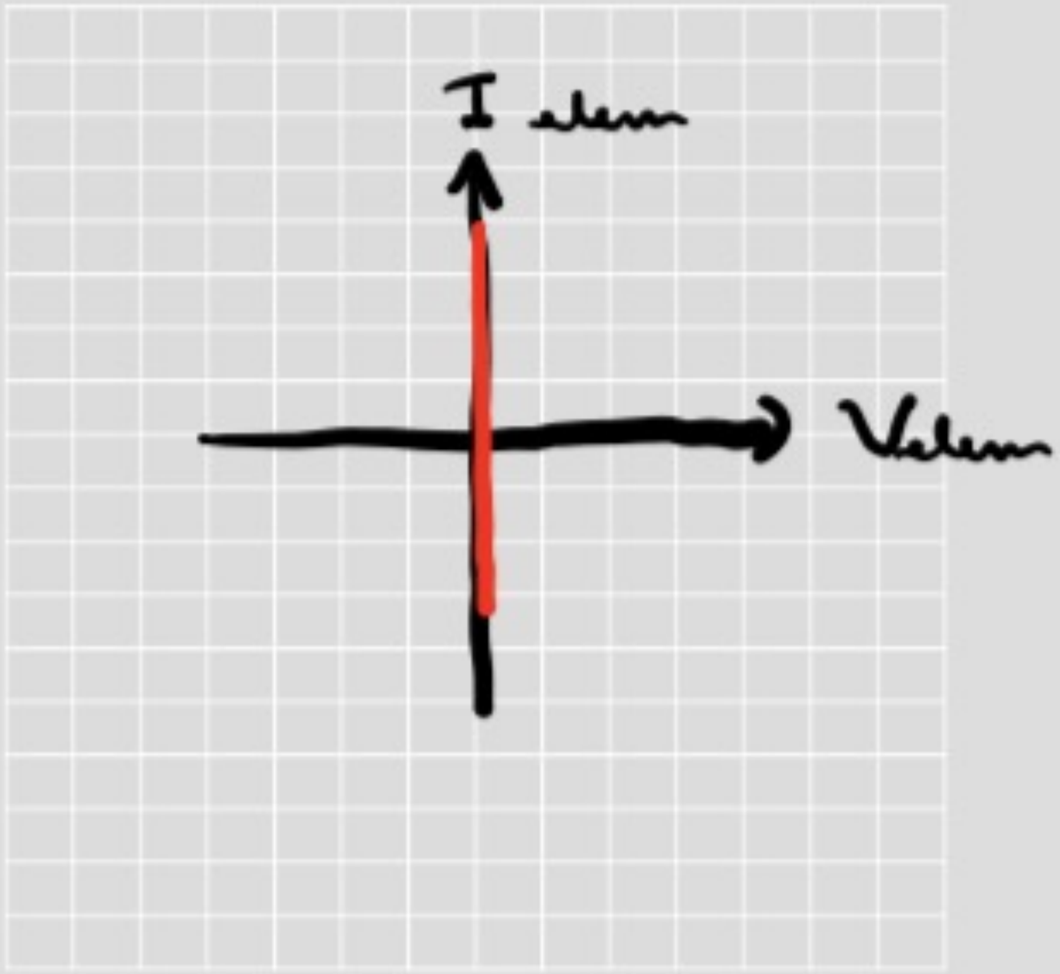
Key circuit elements: Wire



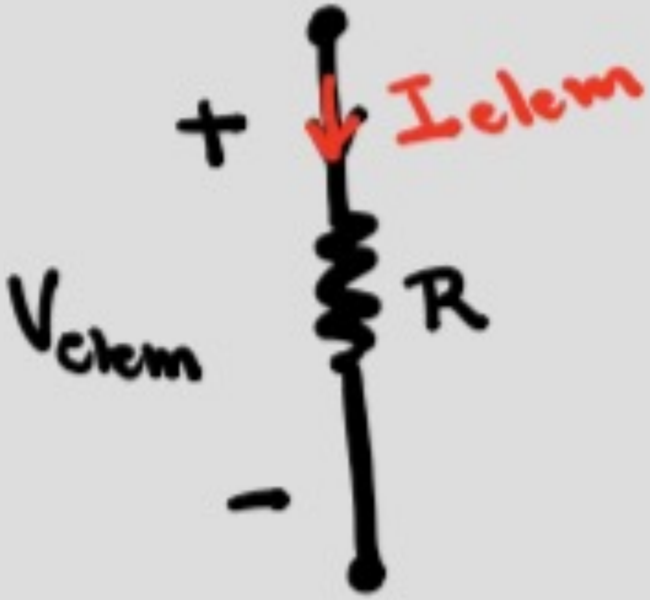
$V_{elem} = 0$

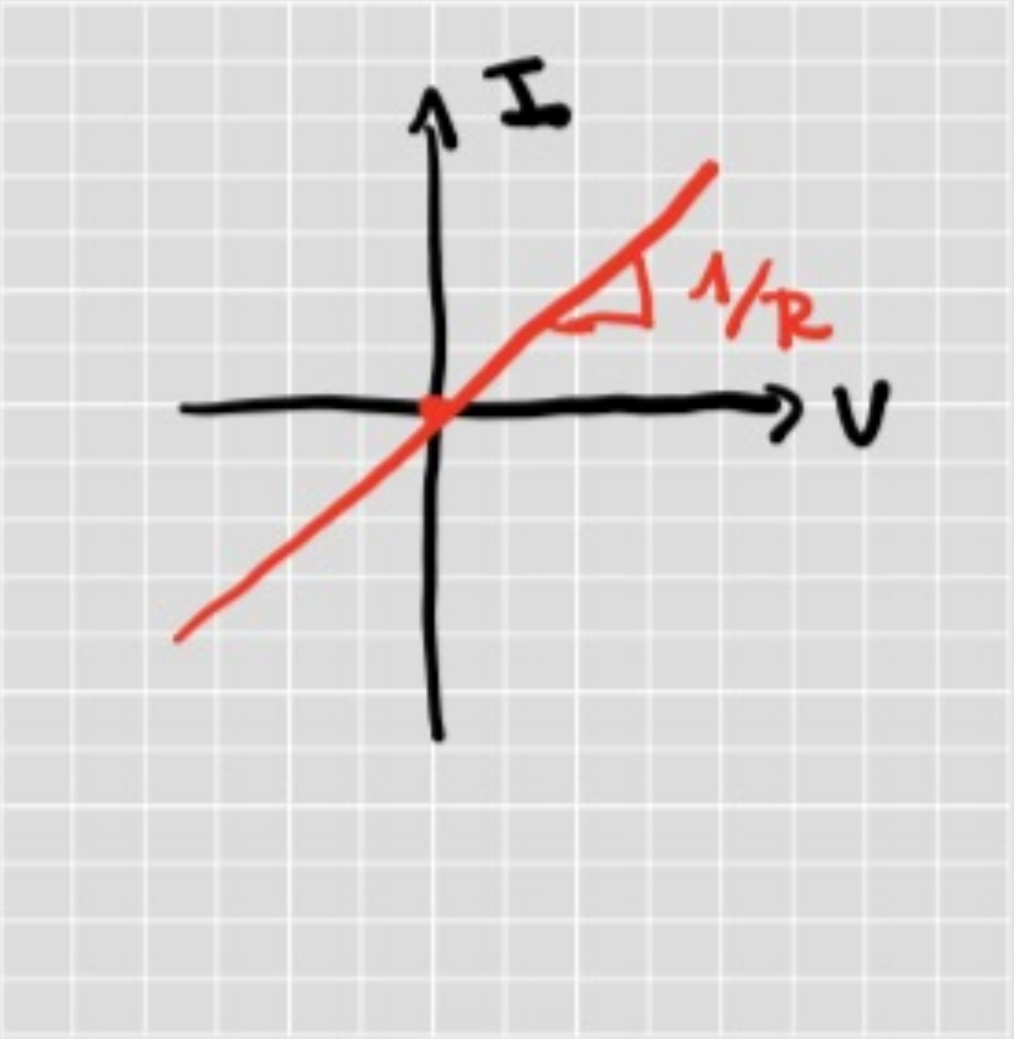
$I_{elem} = ?$

(set by the external circuit)



Key circuit elements: Resistor

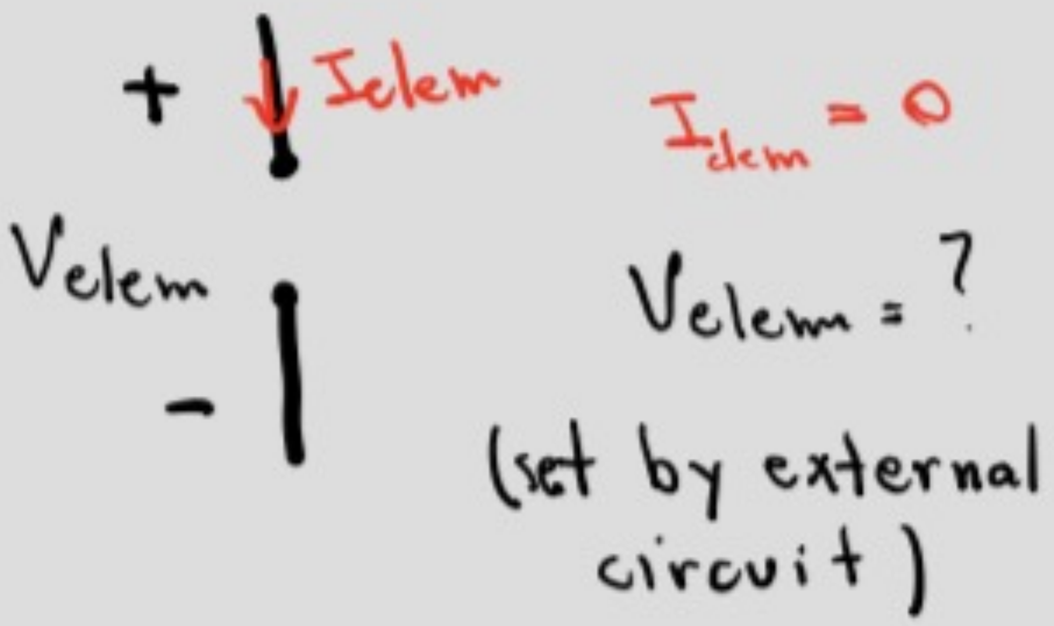


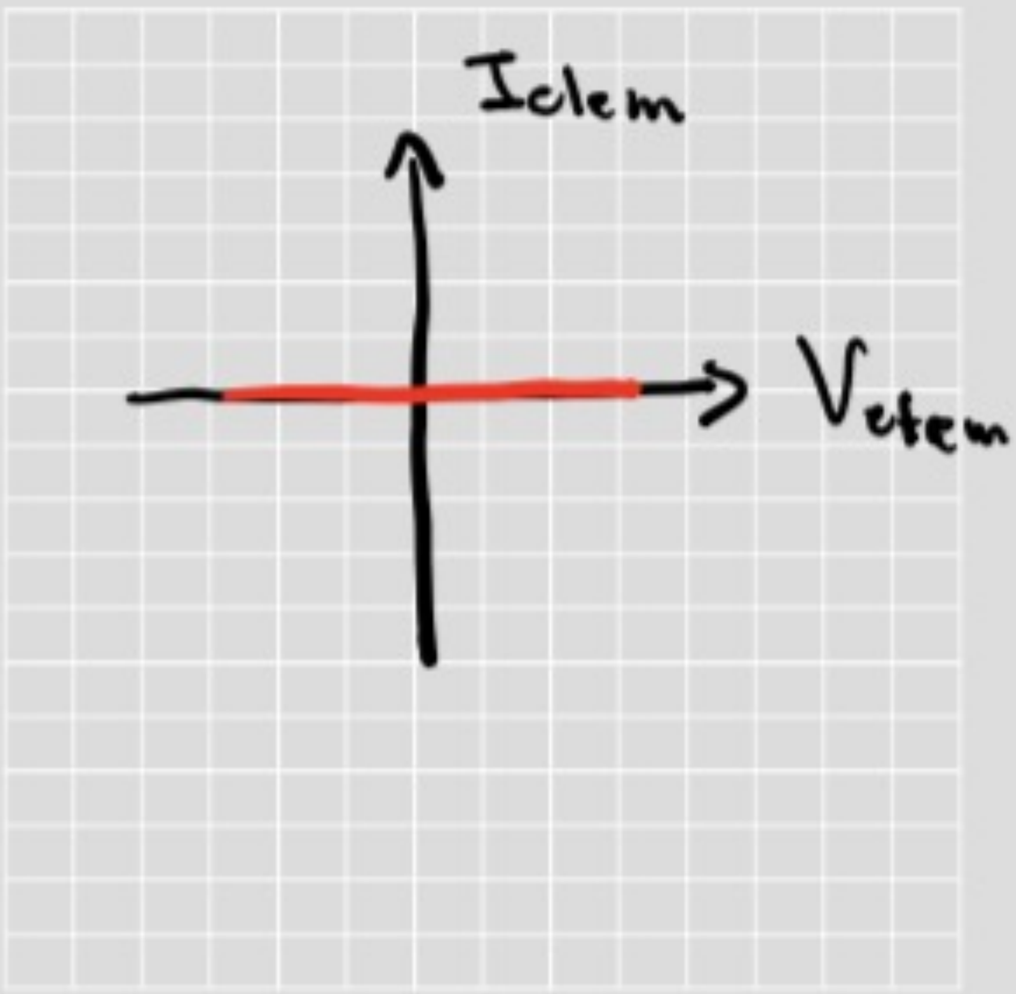


$$V_{elem} = R \cdot I_{elem}$$

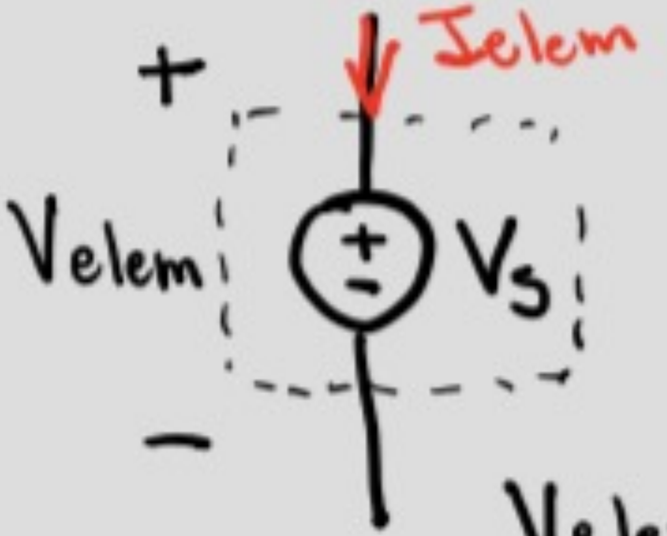
(Ohm's law)

Key circuit elements: Open circuit





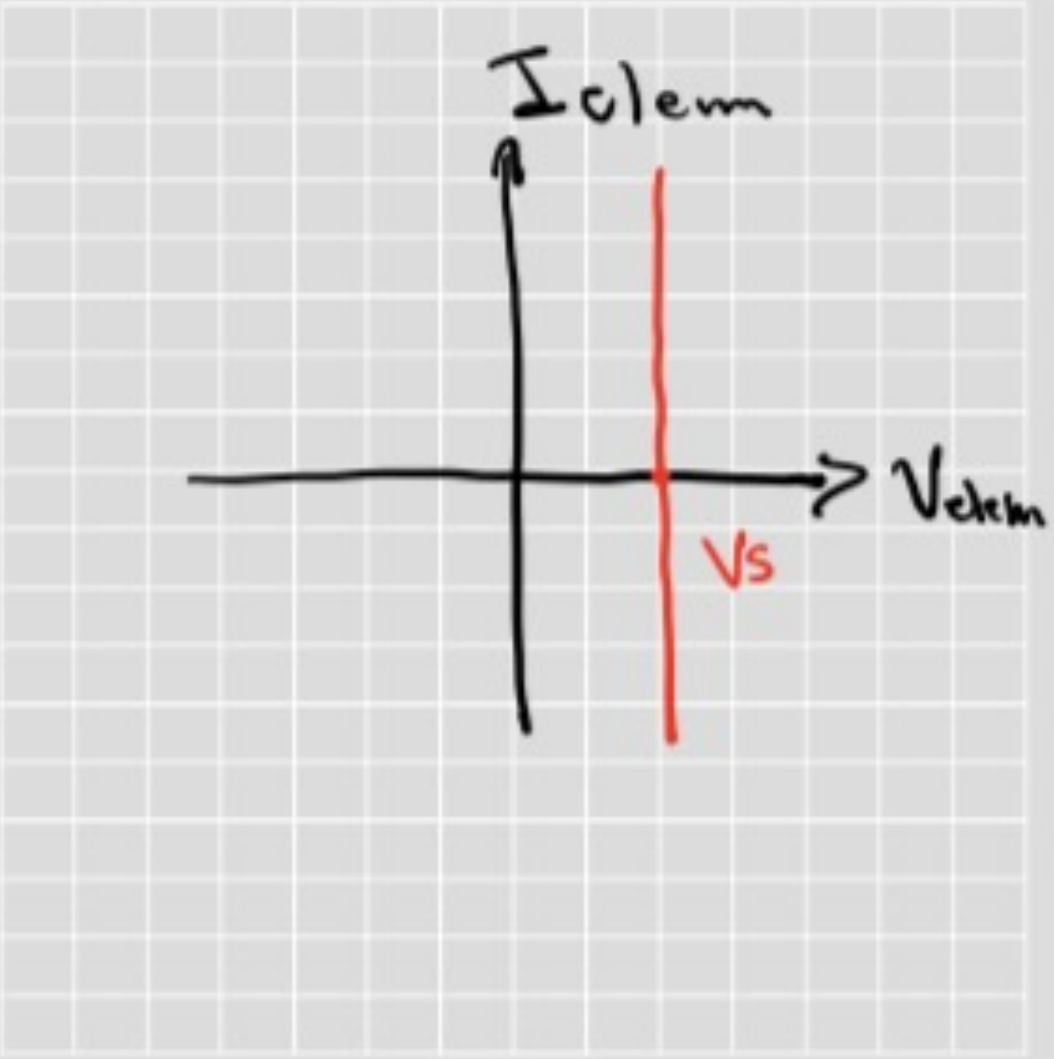
Key circuit elements: Voltage Source

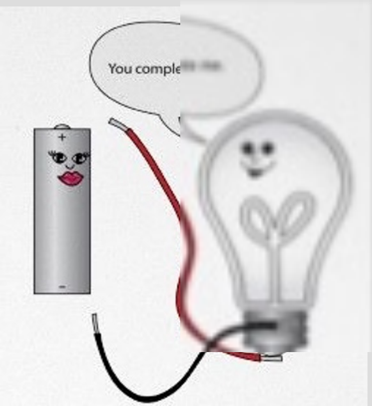


$V_{elem} = V_s$

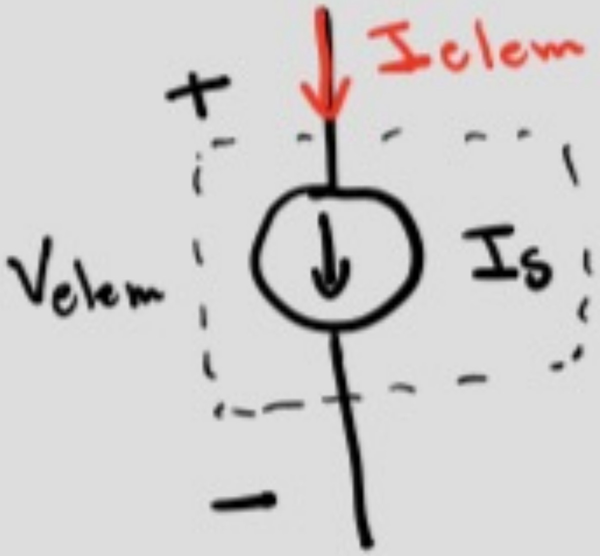
$I_{elem} = ?$

(set by external circuit)





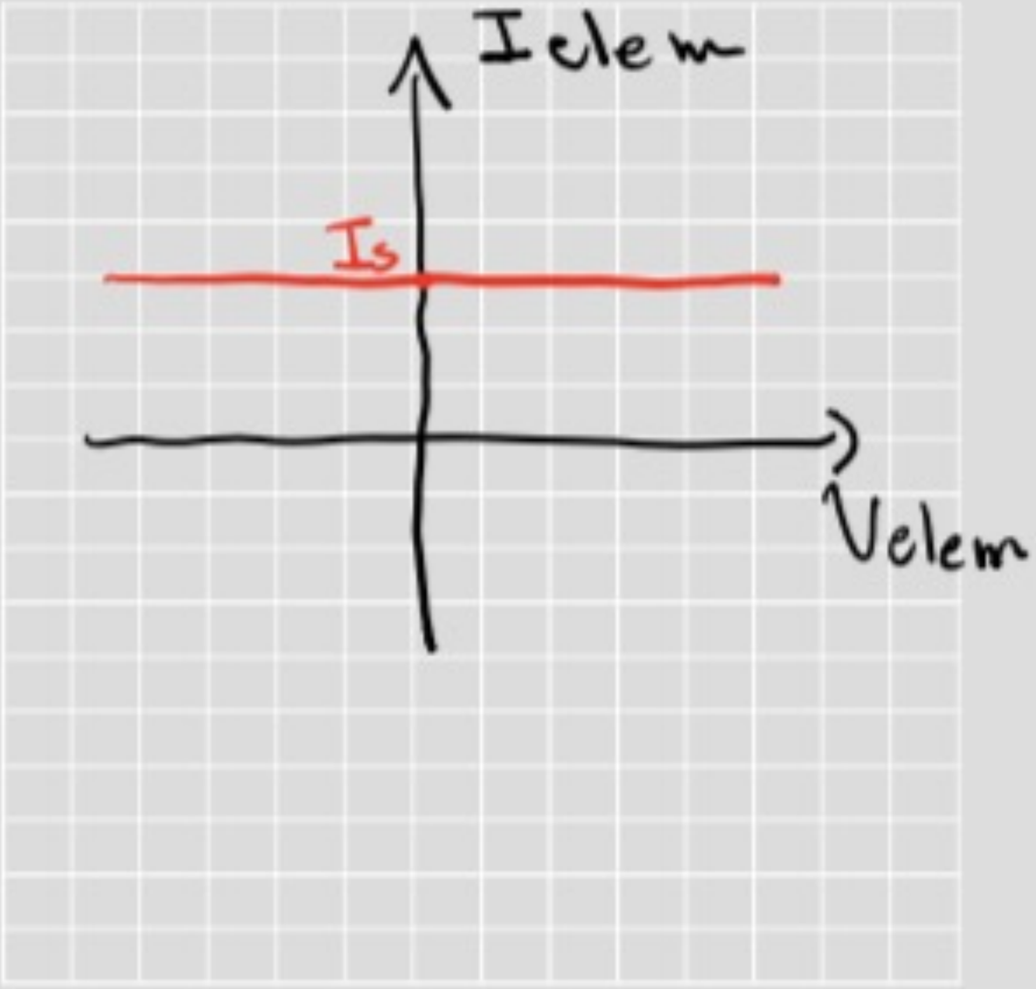
Key circuit elements: Current Source



$I_{elem} = I_s$

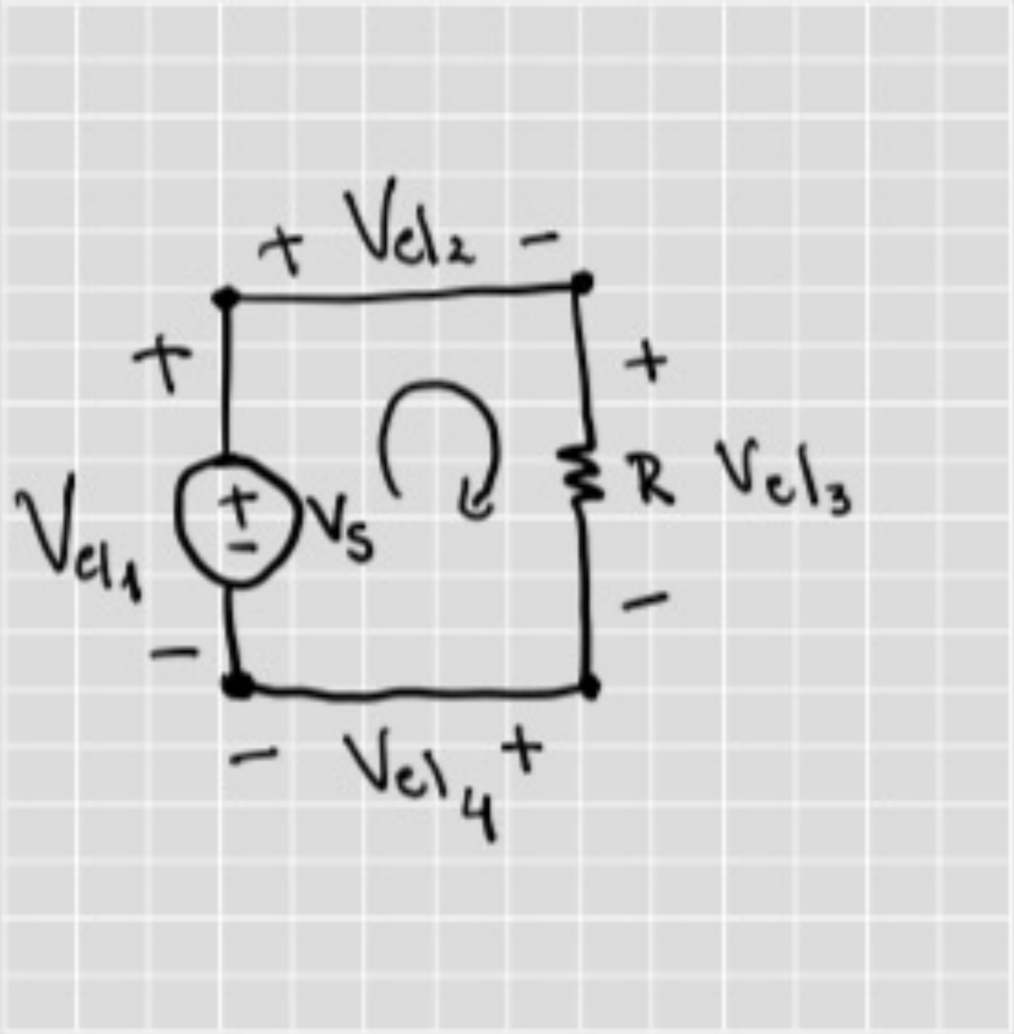
$V_{elem} = ?$
(set by ext. circuit)

Velement and Ielement <u>can</u> be positive or negative

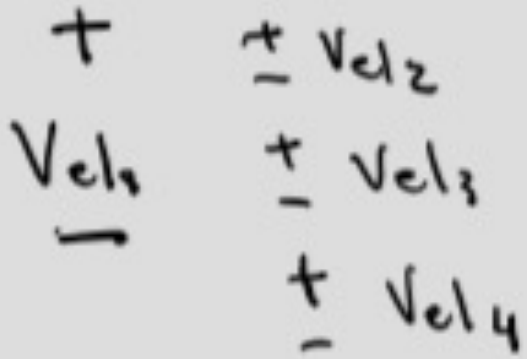


Rules for circuit analysis: Kirchoff's Voltage Law (KVL)

Sum of Voltages across the elements in a loop equal zero



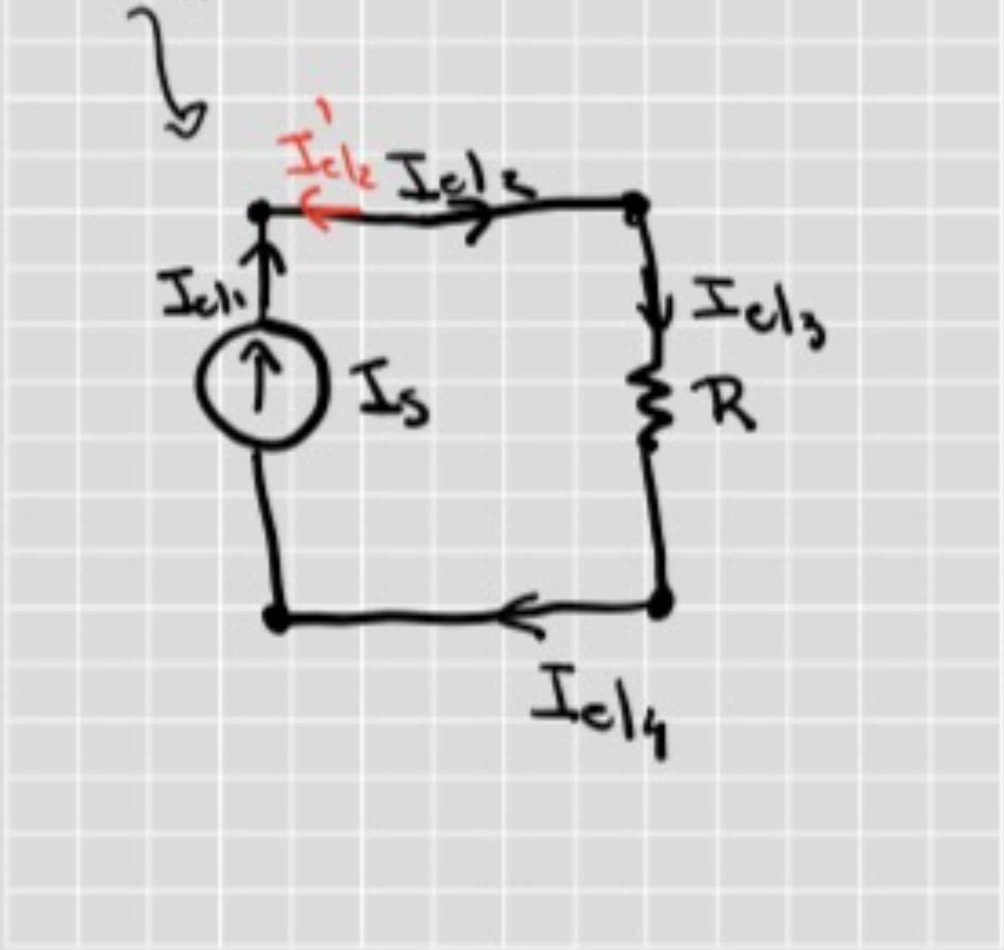
$$V_{el_1} - V_{el_2} - V_{el_3} - V_{el_4} = 0$$



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

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

$I_{cl1} + I_{cl2} = 0$



$I_{cl1} = I_{cl2}$

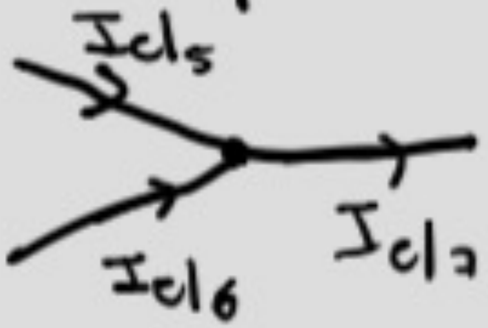
$I_{cl2} = I_{cl3}$

$I_{cl3} = I_{cl4}$

~~$I_{cl4} = I_{cl1}$~~

$I_{cl2} - I_{cl1} = 0$

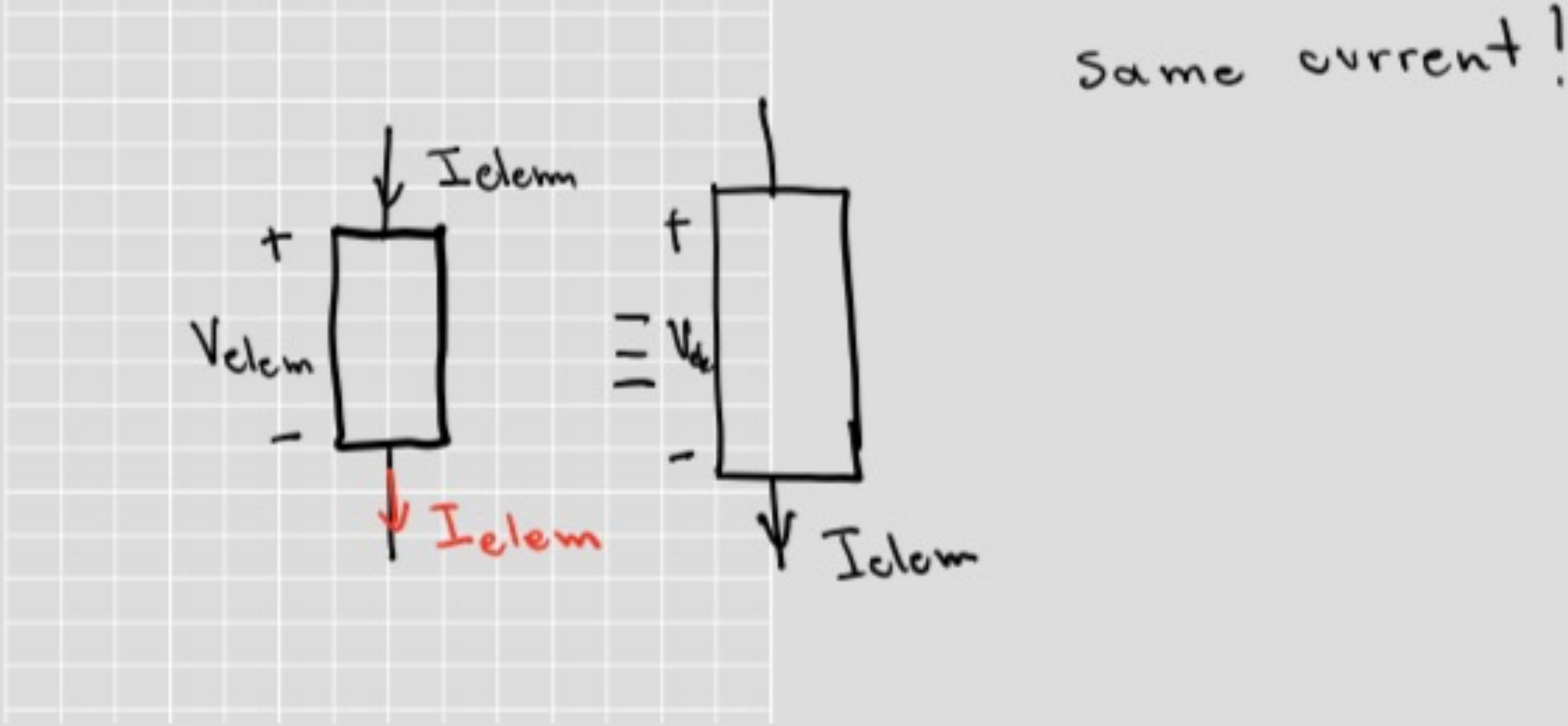
Example 2:



$I_{cl5} + I_{cl6} = I_{cl4}$

Rules for circuit analysis: KCL within the element

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



Rules for circuit analysis: KCL within the element

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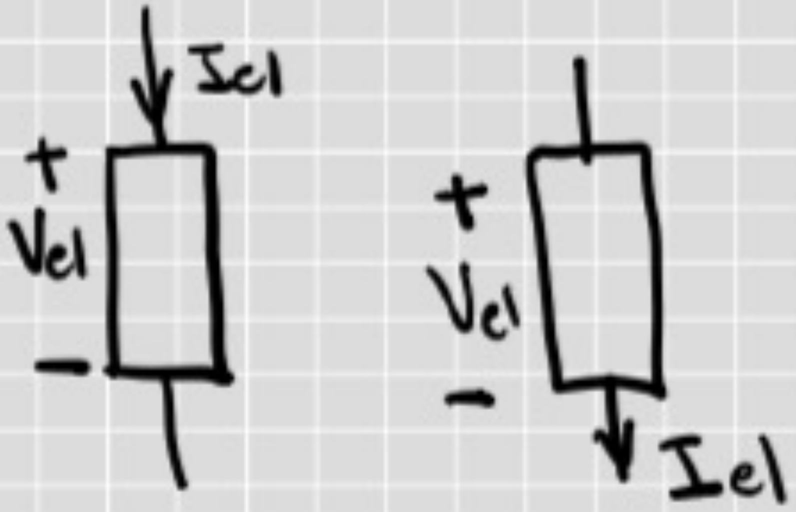


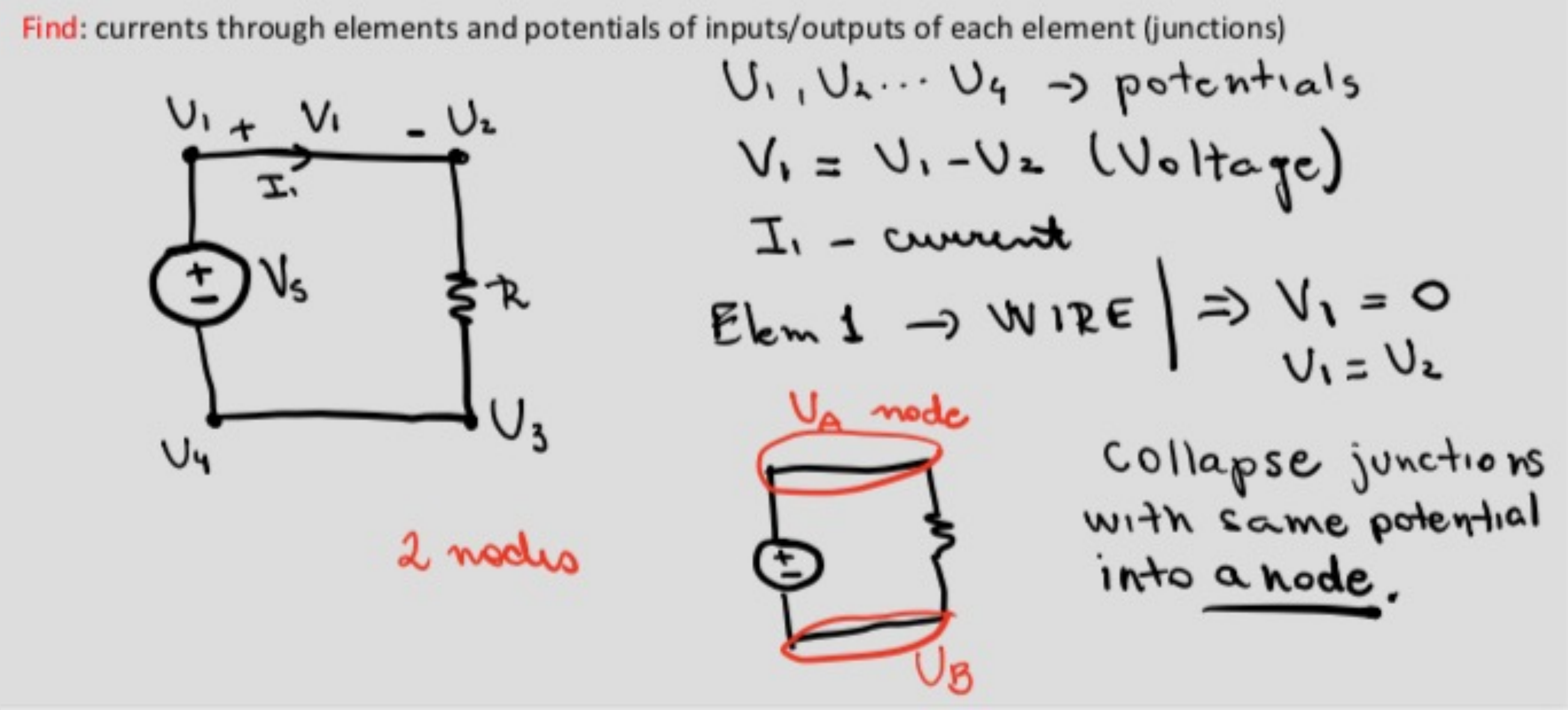
Both allowed!

Ielem goes into a ⊕ or out of a ⊖ terminal

Passive sign convention

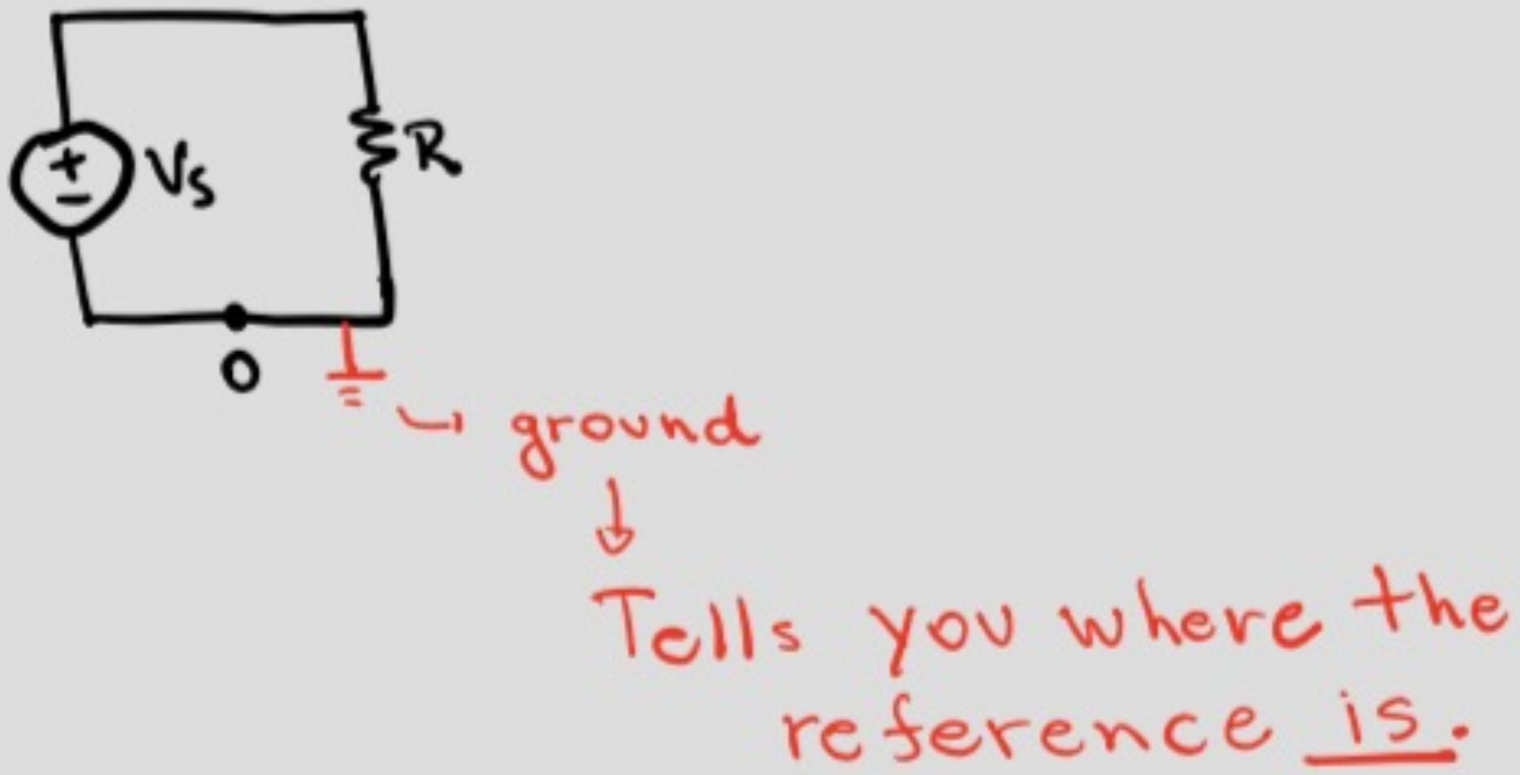
Circuit Analysis Algorithm

Voltage = difference of two potential



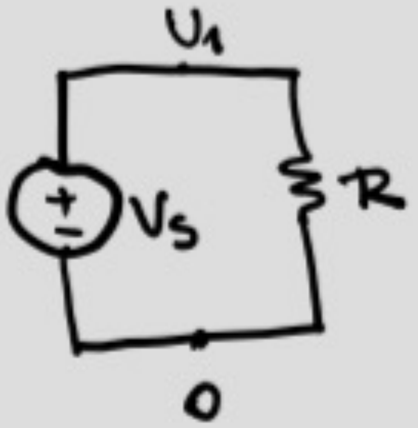
Circuit Analysis Algorithm : step 1

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



Circuit Analysis Algorithm : step 2

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

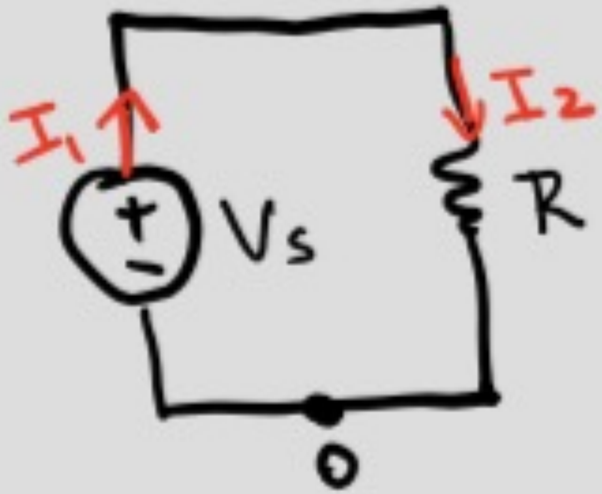


$$U_1 - 0 = U_1 = V$$

Voltage between node 1 and node "0"

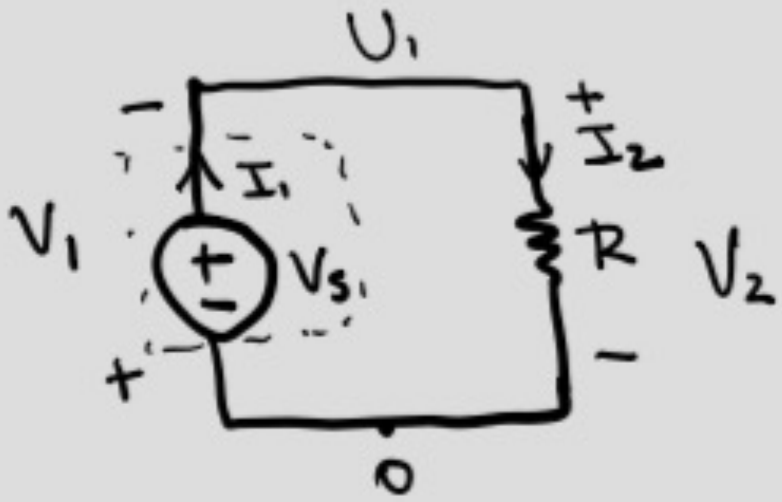
Circuit Analysis Algorithm : step 3

Label all branch currents with I_m
Arbitrarily pick directions of I_m
$[I_1 \ldots I_k]$



Circuit Analysis Algorithm : step 4

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



Circuit Analysis Algorithm : step 5

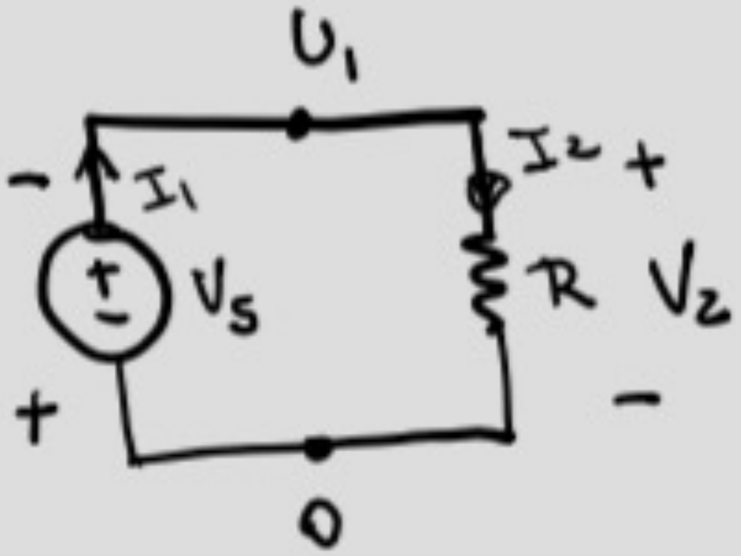
Formulate $A\vec{x} = \vec{b}$

$$\vec{x} = \begin{bmatrix} I_1 \\ \vdots \\ I_k \\ v_1 \\ \vdots \\ v_{N-1} \end{bmatrix}$$

→ vector of unknowns

Circuit Analysis Algorithm : step 6

Use KCL to fill as many rows of A as possible (linear independence) # Nodes -1 = N-1



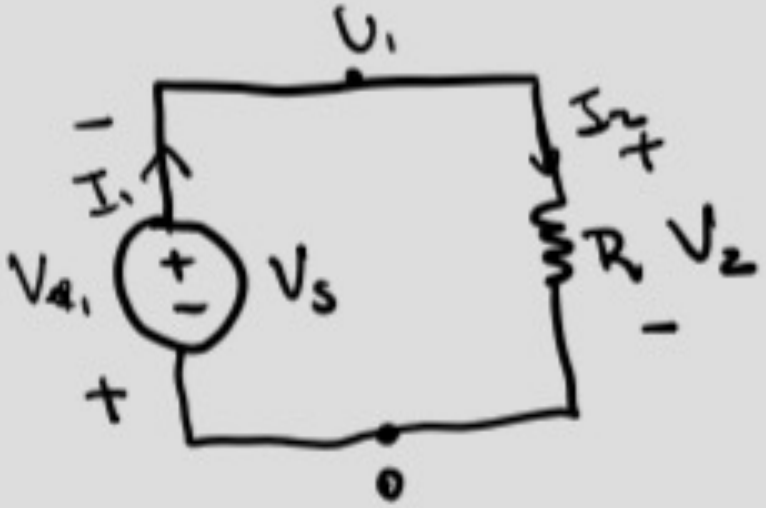
$$I_1 = I_2$$

$$I_1 - I_2 = 0$$

$$\begin{bmatrix} 1 & -1 & 0 \\ & & \\ & & \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ V_1 \end{bmatrix} = \begin{bmatrix} 0 \\ \\ \end{bmatrix}$$

Circuit Analysis Algorithm : step 7

Use current-voltage relationships for each element to fill the rest of the A matrix



Voltage element: $V_{el_1} = -V_s$

$V_{el_1} = 0 - U_1 = -U_1$

$U_1 = V_1$ ✓

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

⇓

$U_1 = V_s$

$I_1 = V_s / R$

$I_2 = V_s / R$

Resistor $V_{el_2} = I_2 \cdot R$

$V_{el_2} = U_1 - 0 = U_1$

$U_1 = I_2 R$

$I_2 R - U_1 = 0$ ✓