(p1)

Module 2, Lecture 1

EECS 16A
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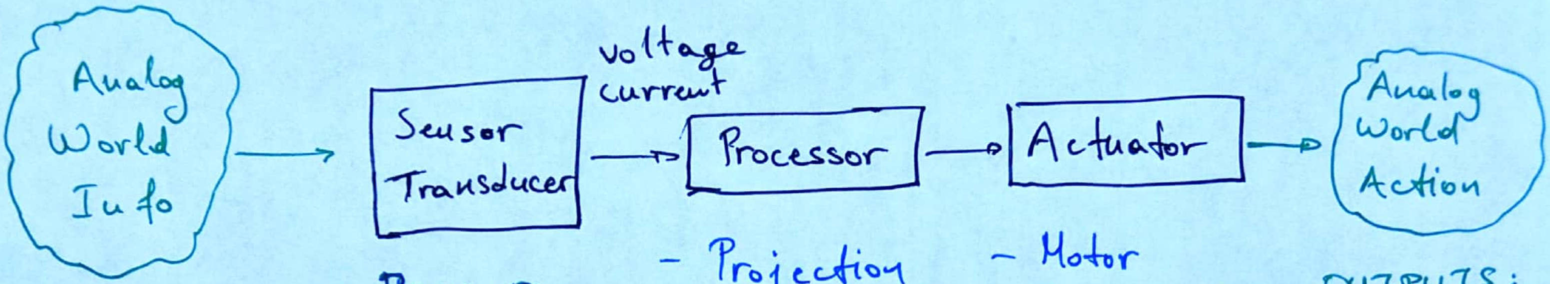
Today: * Sensing, Processing and Actuating Systems
* Intro to Circuit Analysis } Note 11



INPUTS:
Light
Sound
Heat
Pressure
Radiation

Sensor / Transducer:
- Pressure Sensor
- Light Sensor
- Microphone
- Camera

Processor:
- Projection
- Filtering
- Algorithms

Actuator:
- Motor
- Hydraulic Act.
- Speaker
- Screen (Display)

OUTPUTS:
Video
Movement
Sound

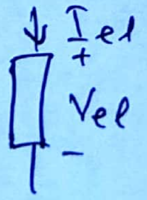
Electrical Circuit Analysis (tool) SPICE

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

Circuit Diagram

Collection of elements with some voltage <u>across</u> them and some current <u>through</u> them.

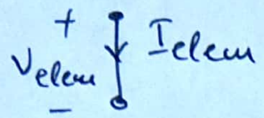
Generic Element:



Note: Voltage is a <u>relative</u> quantity (always measured in between <u>two</u> points)

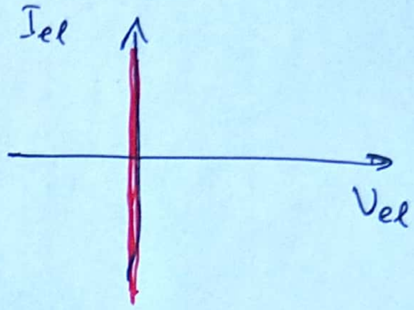
Useful, Common Circuit Elements

① Wire

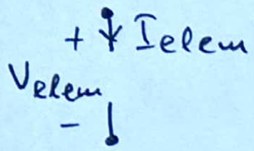


$V_{elem} = 0$

$I_{elem} = ?$ (set by ext ckt)

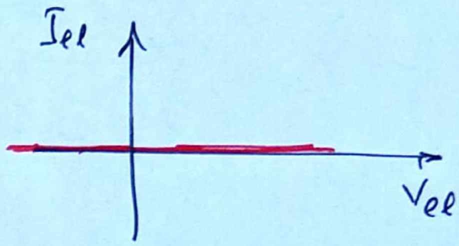


② "Open-Circuit"

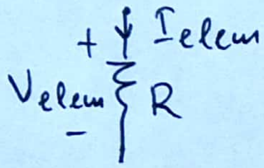


$V_{elem} = ?$ (set by ext ckt)

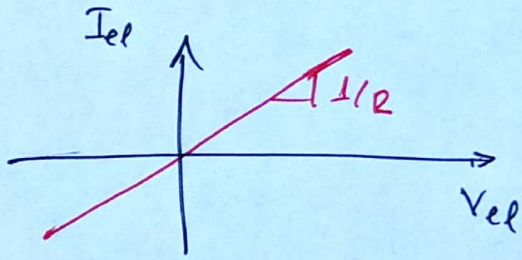
$I_{elem} = 0$



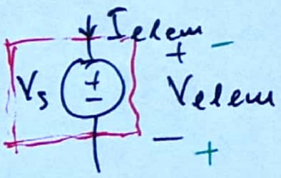
③ Resistor



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

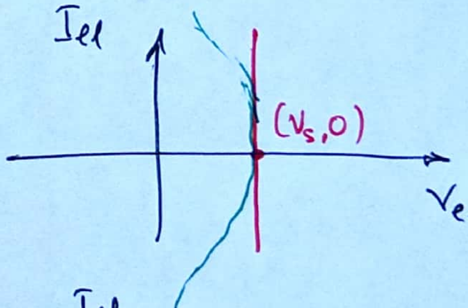


④ Voltage Source

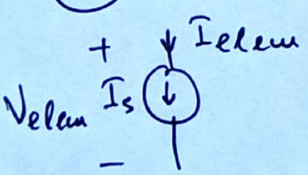


$V_{elem} = -V_s$

$I_{elem} = ?$ (set by ext ckt)



⑤ Current Source



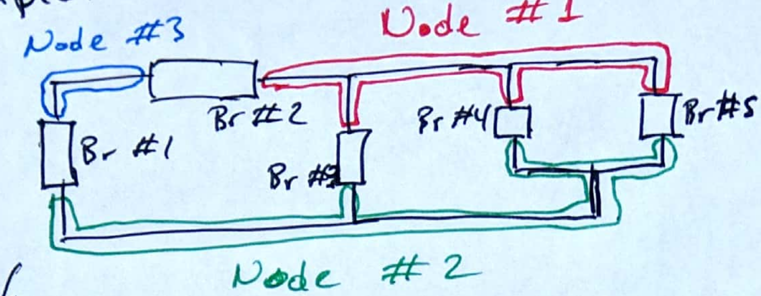
$V_{elem} = ?$ (set by ext ckt)

$I_{elem} = I_s$

Note: I_{el}, V_{el} can be positive and negative!

Nomenclature of Ckt Diagrams: Nodes + Branches

example:



Node: Any point on the ckt where two or more elements intersect (meet)

Branch: Any ckt element apart from wires and open ckts

↓

3 Nodes

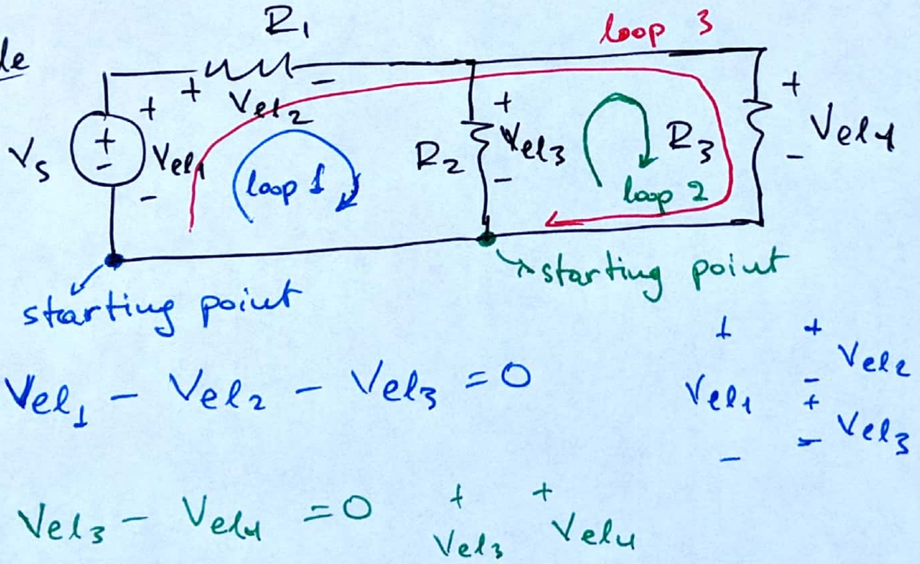
5 Branches

Rules (laws) for Circuit Analysis:

(A) Kirchhoff's Voltage Law (KVL):

The sum of element voltages around a loop is equal to 0.

example



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

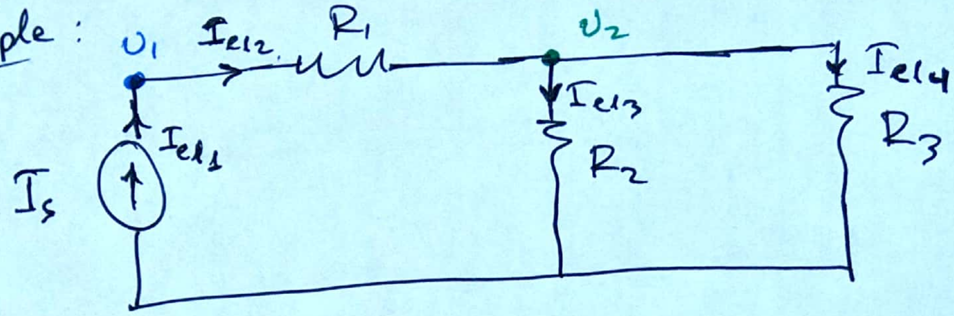
$V_{el_3} - V_{el_4} = 0$

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

(B) Kirchhoff Current Law (KCL):

The sum of the current entering a node <u>must</u> equal the sum of the current exiting the node.

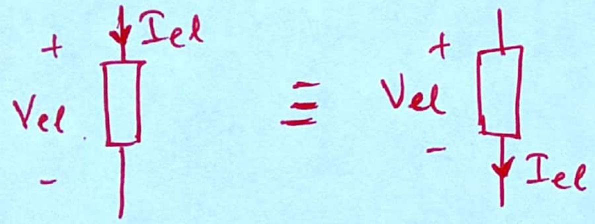
<u>example</u>:



KCL on v_1: $I_{el1} = I_{el2}$

KCL on v_2: $I_{el2} = I_{el3} + I_{el4}$

KCL within the elements



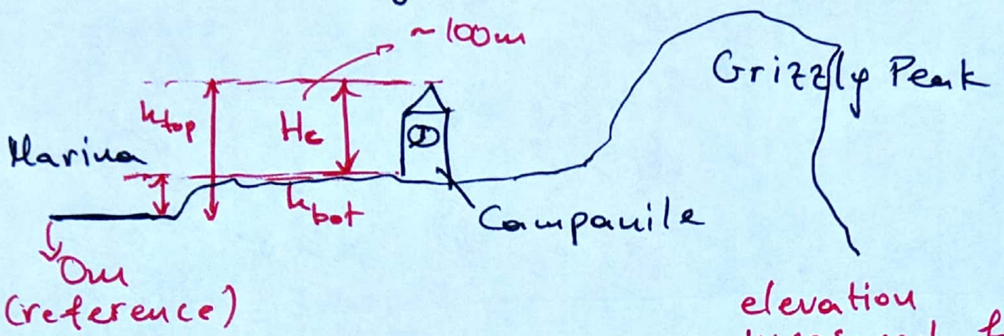
<u>Passive Sign Convention</u>:

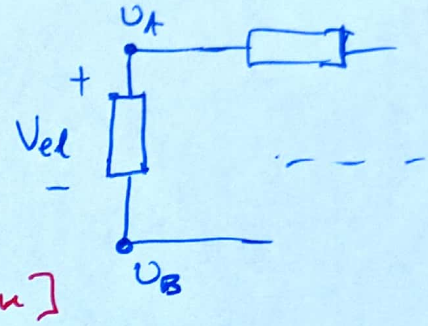
I_{el} is entering the "+" terminal or exiting the "-" terminal!

Voltage Reference – Node Voltages (Potentials)

Element Voltage ⟷ Height measurement

Node Voltage (Potential) ⟷ Elevation (altitude) measurent





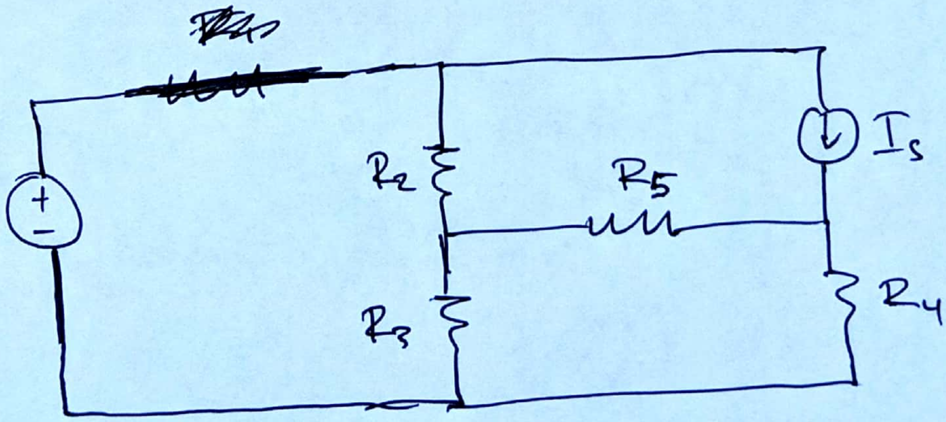
height [m] $H_c = h_{top} - h_{bot}$ → elevation [m] measured from sea level (reference)

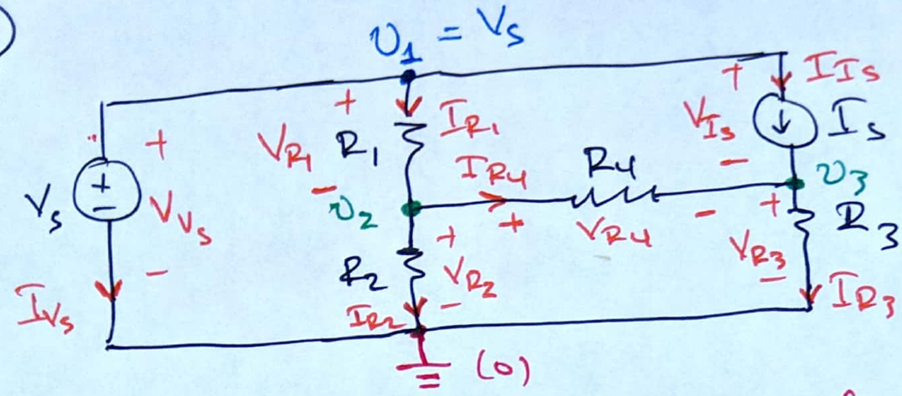
element voltage [V] $V_{el} = v_A - v_B$ → node voltages [V] measured from a reference point in our ckt (ground) ⏚

Node Voltage Analysis (NVA) algorithm

Goal: Find all node voltage and all element currents

example





Step 1: Pick and label a reference node. (0 or ground)

Step 2: Label all nodes whose voltage is set by voltage sources

Step 3: Label all remaining nodes (unknown)

Step 4: Label all element current and element voltages according to passive sign convention.

Step 5: Write a KCL equation for every node with unknown voltage.

v_2 : $I_{R_1} = I_{R_4} + I_{R_2}$

v_3 : $I_{R_4} + I_{I_s} = I_{R_3}$

Step 6: Express all element currents as functions of element voltages and circuit component characteristics

$$I_{R_1} = \frac{V_{R_1}}{R_1}, \quad I_{R_2} = \frac{V_{R_2}}{R_2}, \quad I_{R_3} = \frac{V_{R_3}}{R_3}, \quad I_{R_4} = \frac{V_{R_4}}{R_4}$$

(Ohm's law)

Step 7: Substitute all element voltages with node voltages in your step 6 equations.

$$I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{v_1 - v_2}{R_1} = \frac{V_s - v_2}{R_1}$$

$$I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{v_2 - 0}{R_2} = \frac{v_2}{R_2}$$

$$I_{R_3} = \frac{V_{R_3}}{R_3} = \frac{v_3 - 0}{R_3} = \frac{v_3}{R_3}$$

$$I_{R_4} = \frac{V_{R_4}}{R_4} = \frac{v_2 - v_3}{R_4}$$

Step 8: Substitute element currents from Step 7 into the KCL equations from Step 5.

$$I_{R_1} = I_{R_4} + I_{R_2} \Rightarrow \frac{V_s - v_2}{R_1} = \frac{v_2 - v_3}{R_4} + \frac{v_2}{R_2} \qquad (1)$$

$$I_{R_4} + I_{I_S} = I_{R_3} \Rightarrow \frac{v_2 - v_3}{R_4} + I_s = \frac{v_3}{R_3} \qquad (2)$$

Step 9: Solve

Use G.E. to solve the system of equations (1), (2).