Circuit Theory and Electronics Fundamentals

Lecture 1: Course introduction

- Course introduction
- Circuits: node, branch, loop
- Current and voltage sources
- Resistors, Kirchoff laws, power,
- Resistor series and parallel, voltage and current dividers

About the course

- Basic circuit theory and electronics
- Circuits: components and wires
- Basic components:
  - Voltage and current sources, independent or dependent (controlled)
  - Linear components: resistors, capacitors, inductors, transformers
  - Non-linear components: diodes and transistors
- Basic circuits
  - Circuits containing only linear components
  - Circuits containing linear and non-linear components

About the course (continued)

- Circuit topology: nodes, branches and loops
- Voltage and current signals: static and sinusoidal
- Power and energy
- Analyses: static, time and frequency analysis
- Popular circuits: amplifiers, filters, rectifiers, envelope detectors, logic gates and operational amplifiers

TÉCNICO LISBOA

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- IST/DEEC: assistant professor
- INESC-ID: researcher
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- https://scholar.google.com/citations?user=ai6ekBAAAAAJ&hl=en&authuser=1

The classes

- Theory lectures
  - 2 x 1h30 per week
- Problems classes
  - 8 sessions x 1h30
- Laboratory sessions
  - 5 sessions x 1h30 per week

Lab sessions

- Groups of 3 students
- 5 lab assignments: 5 circuits to study
- Each assignment: each group shows its work in 10 minutes
- Report:
  - Theoretical analysis: Octave code
  - Simulation analysis: Ngspice code
  - Documentation: report written using Latex
- Marking: very good(4), good(3), ok(2), bad(1), very bad(0)

Lab evaluation criteria

- The lab instructor has 10 minutes to
  - Git clone your group’s git repository
  - Run the Makefile, which will
    - Run Octave and generate data and figures for the report
    - Run Ngspice and generate data and figures for the report
    - Compile the Latex report and produce the pdf file
  - Make sure the above works *flawlessly*
  - Check the quality of the work, make sure you don’t have obvious mistakes

Software

- Ubuntu 18.4 or 20.4 Linux distribution
  - Real or virtual machine, 40+ GB recommended size
- Linux tools:
  - Bash: Linux terminal command interpreter
    - Useful commands: ls, cd, find, grep, sed
  - Make: (build) procedure automation tool
  - Text editor (Any but Emacs or Vim recommended).
- Ngspice: circuit simulator
- Octave: maths tool
  - Open-source free of charge alternative to Matlab
- Tex Live (full installation): Latex text processor

Evaluation

- Exam or 2 tests:

  T=max{ av(T1,T2), E1, E2 }

- Lab: L
- Minimum mark on T or L: 8/20
- Mark:

  M = 0.75T+0.25L

Tests and exams

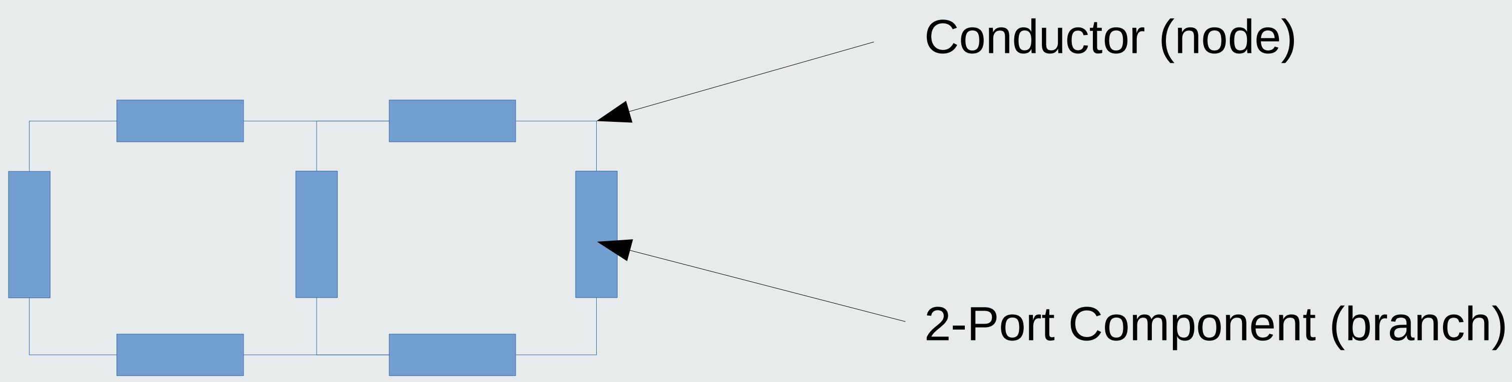
- 2 Tests or Exam
- Duration:
  - Tests: 1h30
  - Exam: 3h00
- Check Fénix for dates
- Exam is divided in 2 parts, which may be used to recover one of the tests
  - Each test may only be recovered once

Bibliography

- The Internet: Google it!
- Lecture slides
- Exercises and their resolution
- Lab materials
- Recommended bibliography on Fénix

Let’s start: Electric Circuits!

2-Port Components (branches) connected by Conductors (nodes)



Lumped elements approximation: no notion of physical distance => no wave propagation or radiation

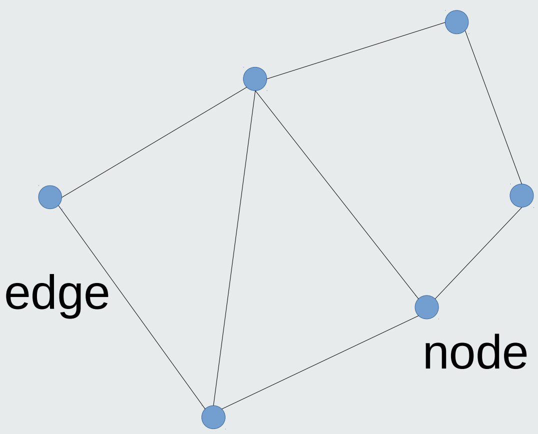
Circuits as Graphs

Simplest mathematical model for a circuit:

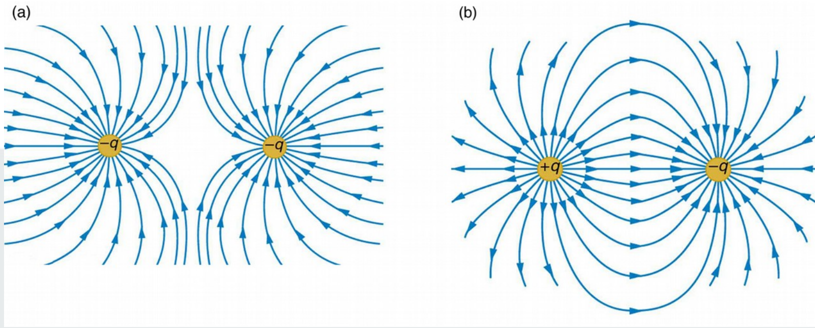
A graph G=(V,E)

V: set of vertices or nodes

E: set of edges or branches (may be labelled to identify function)

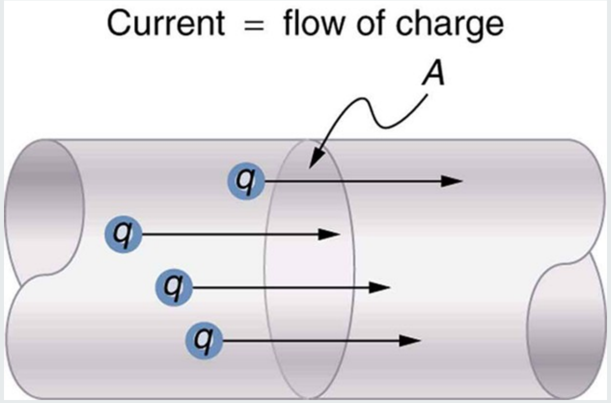


Charge and Electric Field



Physical quantities

- Charge (Q): Coulomb (C)
- Current (I): Ampere (A=C/s)
- Voltage (V): Volt (V=J/C)



1V

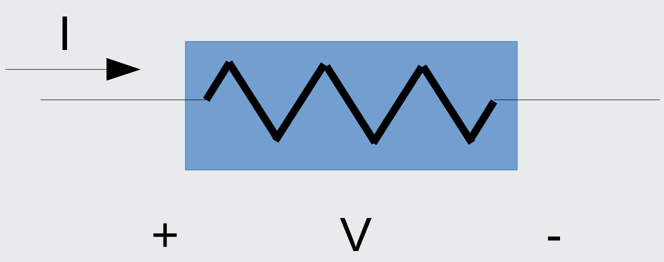
E: electric field

GND

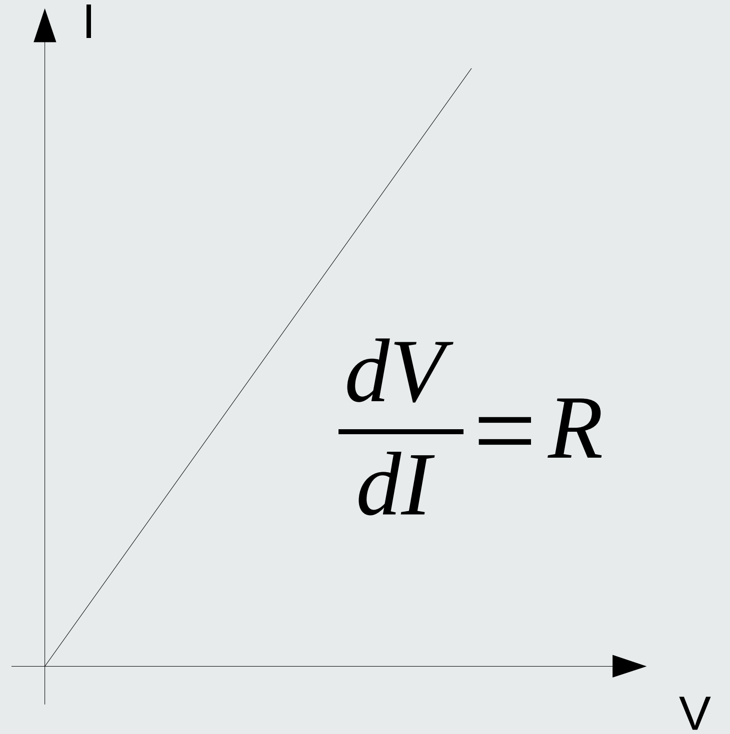
Reference electric potential: 0V

It takes 1 Joule of energy to move a 1 Coulomb charge from GND to 1V Electric Potential

Component: Resistor

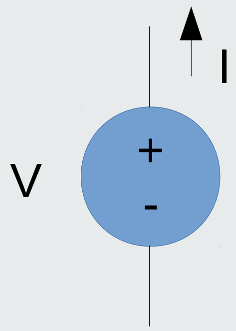


- Linear resistor
- Ohm’s law: V = RI
- G = 1/R (conductance)
- R is expressed in Ohm: Ω = V/A
- G is expressed in Siemens: $S = \Omega^{-1} = A/V$

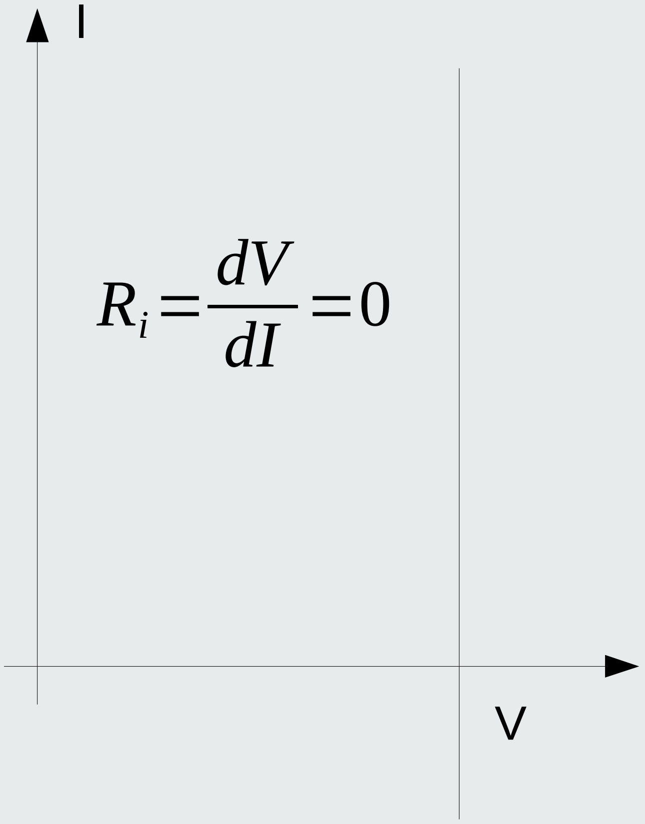


$$\frac{dV}{dI} = R$$

Component: Voltage Source

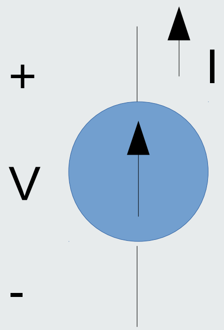


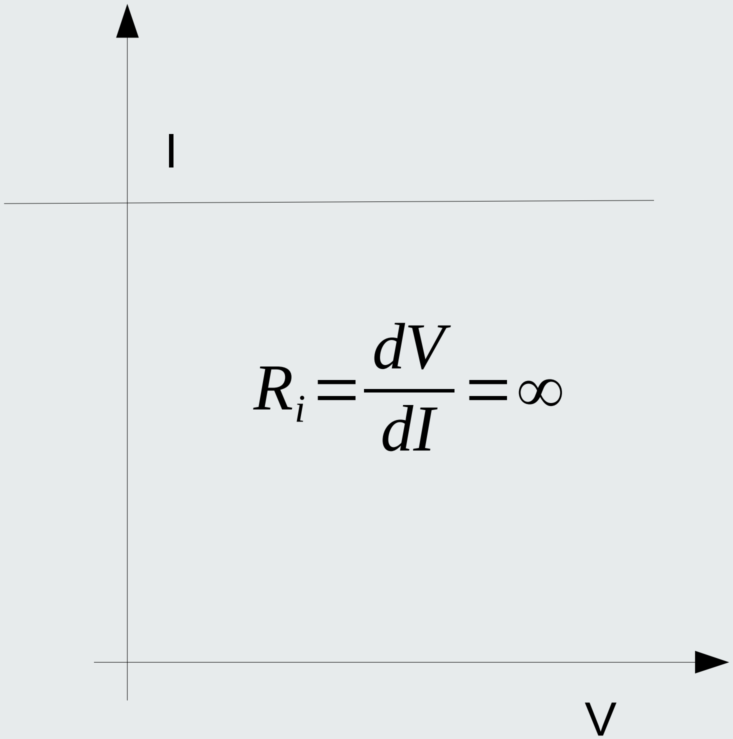
- Imposes voltage V regardless of current I
- Internal resistance is null



$$R_i = \frac{dV}{dI} = 0$$

Component: Current Source





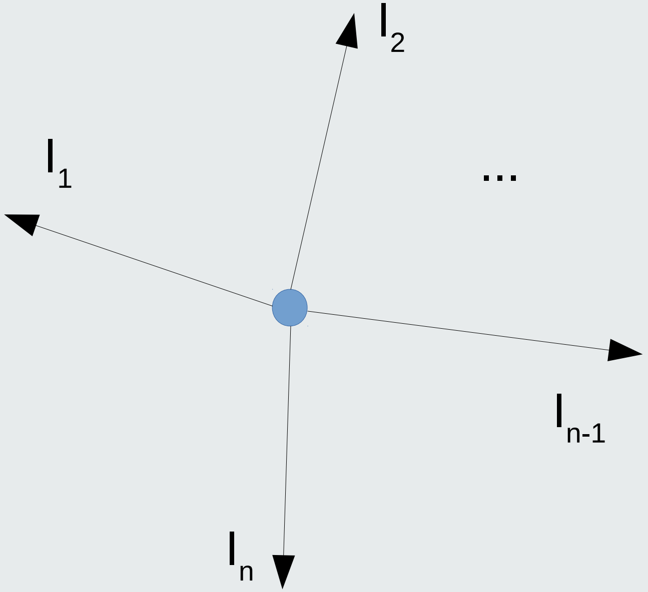
$$R_i = \frac{dV}{dI} = \infty$$

- Imposes current I regardless of voltage V
- Internal resistance is infinite

Kirchhoff Current Law (KCL)

- KCL: sum of currents converging (diverging) in a node is null

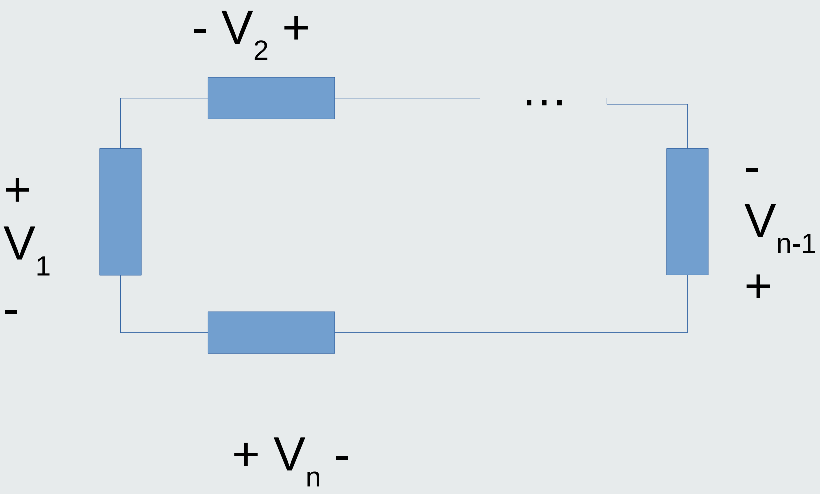
$$\sum_{i=1}^{n} I_i = 0$$



Kirchhoff Voltage Law (KVL)

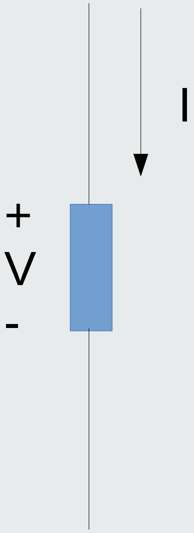
- KVL: sum of Voltages in a circuit loop is null

$$\sum_{i=1}^{n} V_i = 0$$



Power

- Power (P) is a measure of Energy (E) per Time (t) unit
- P(t) used to compute the energy supplied or consumed by a component during a time interval
- Power is expressed in Watt units: W = J / s
- With the directions for Voltage V and Current I as defined in the figure



$$P = V\,I$$

- If P>0 the component is consuming energy
- If P<0 the component is supplying energy

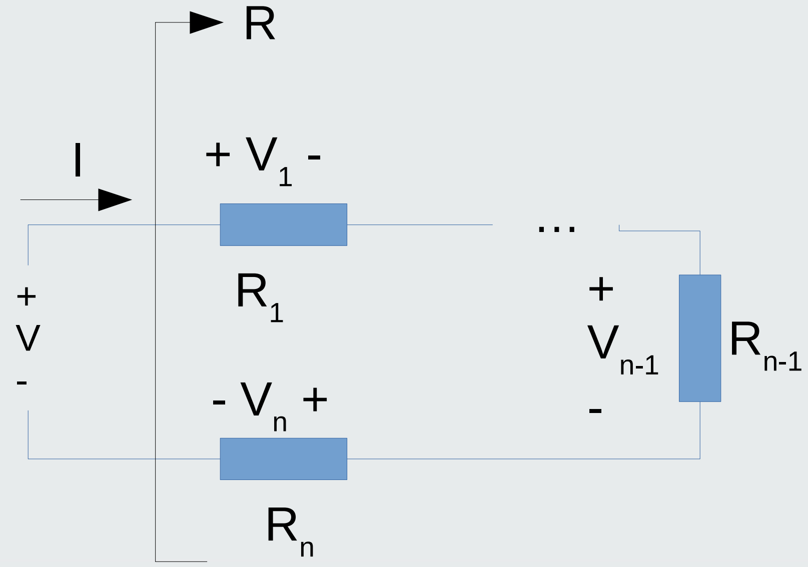
Series of Resistors

$$V=\sum_{i=1}^{n} V_i$$ KVL

$$V=\sum_{i=1}^{n} R_i I$$ Ohm's Law

$$V=\left(\sum_{i=1}^{n} R_i\right) I$$

$$R=\sum_{i=1}^{n} R_i$$



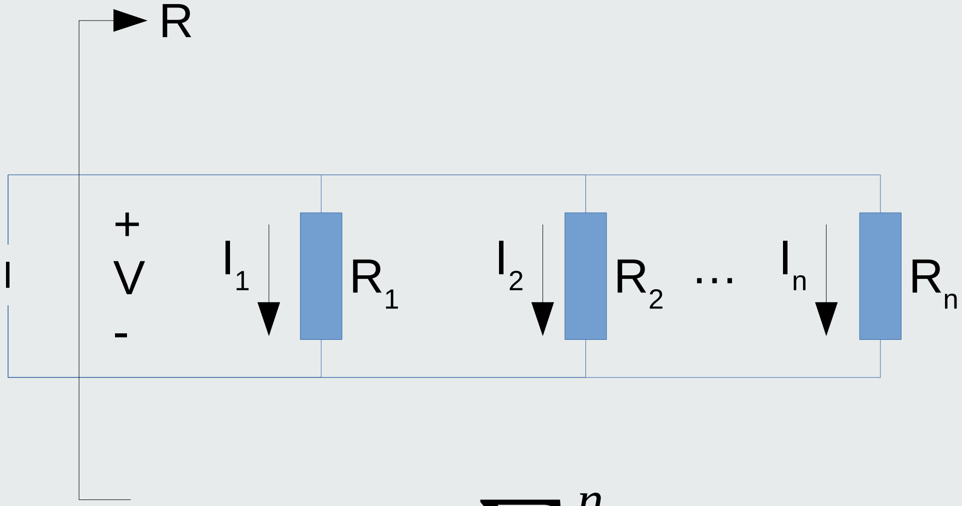
Parallel of Resistors

$$I = \sum_{i=1}^{n} I_i$$ KCL

$$I = \sum_{i=1}^{n} \frac{V}{R_i}$$ Ohm's Law

$$I = \left(\sum_{i=1}^{n} \frac{1}{R_i}\right) V$$

$$R = \frac{1}{\sum_{i=1}^{n} \frac{1}{R_i}}$$



$$G = \sum_{i=1}^{n} G_i$$

Voltage Divider

$$V_i = R_i I$$

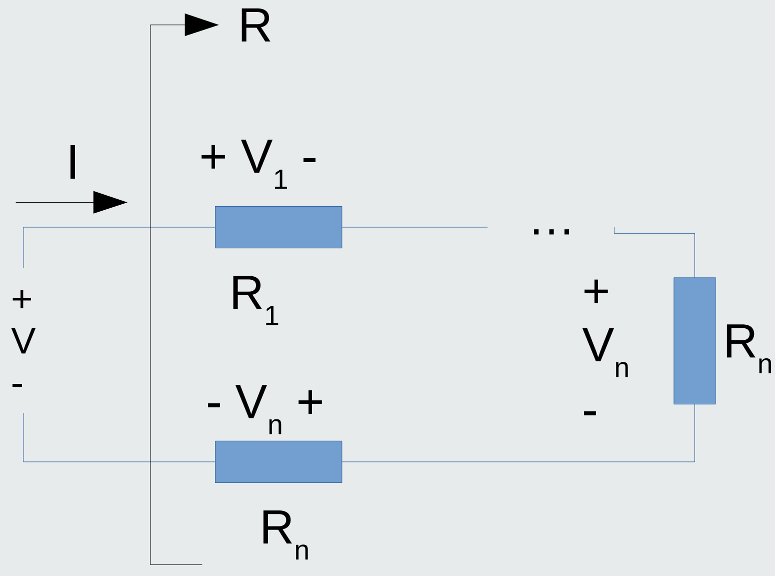
$$V_i = R_i \frac{V}{R}$$

Ohm's Law

$$R = \sum_{j=1}^{n} R_j$$

R Series

$$V_i = \frac{R_i}{\sum_{j=1}^{n} R_j} V$$

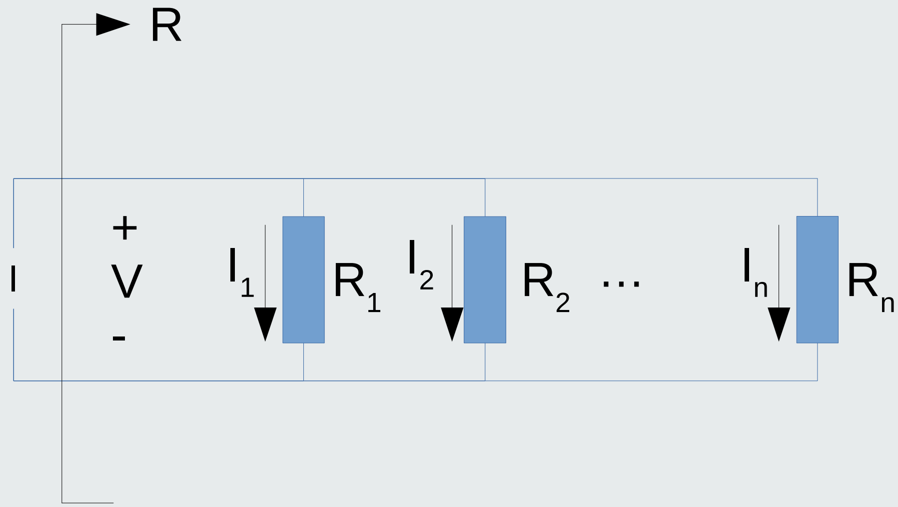


Current Divider

$$I_i = \frac{V}{R_i}$$

Ohm's Law $$I_i = \frac{(RI)}{R_i}$$

R Parallel $$R = \frac{1}{\sum_{j=1}^{n} \frac{1}{R_j}}$$



$$I_i = \frac{\frac{1}{R_i}}{\sum_{j=1}^{n} \frac{1}{R_j}} I$$

$$I_i = \frac{G_i}{\sum_{j=1}^{n} G_j} I$$

Conclusion

- Circuit, nodes, branches and loops
- Voltage and current sources
- Resistors and Ohm's Law: V= RI
- Power and energy: P=VI, E is integral of power over time
- Kirchoff laws:
  - sum of currents {con|di}verging in node is null
  - sum of voltages {con|di}verging in loop is null
- Series of resistors: sum them up to get equivalent resistor
- Parallel of resistors: sum the conductances up to get equivalent conductance; resistance is the conductance inverse
- Voltage divider: V_i= (R_i/R)*V, where V_i is voltage across resistor R_i in series of resistors having total resistance R connected to voltage source V
- Current divider: I_i= (G_i/G)*I, where I_i is current through resistor R_i in parallel of resistors having total conductance G connected to current source I