



Electricity

Introduction

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First year

Summary

- 1 Electric current
- 2 Voltage and Power
- 3 Electrical Resistance
- 4 Hydraulic Analogy

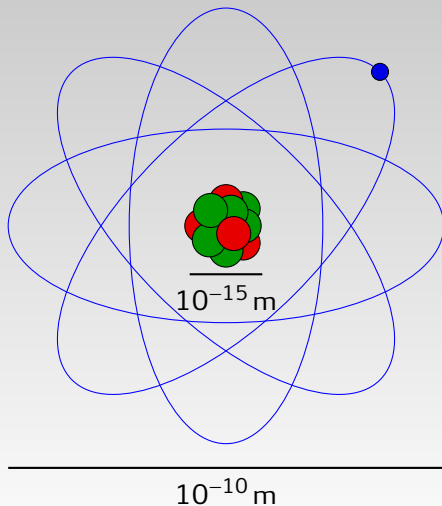
Summary

- 1 Electric current
 - Electron ?
 - Electric current
- 2 Voltage and Power
 - Voltage
 - Power
- 3 Electrical Resistance
 - Definition
 - JOULE effect
- 4 Hydraulic Analogy

Electron ?

- ▶ Elementary particle (light particle or *lepton*)
- ▶ Negative electric charge : $-e$, with $e = 1,602\,176\,535 \times 10^{-19} \text{ C}$
- ▶ Electrons + Protons (charge : e) + Neutrons = Atoms

Atoms : structure and dimensions



Conductors vs Insulators

Conductors : high conductivity / low resistivity

- ▶ métaux (copper, gold, aluminium, iron & alloys)
- ▶ carbon (graphite, diamond, nanotubes...)
- ▶ water (+ electrolytes)
- ▶ human body
- ▶ ground

Insulators : low conductivity / high resistivity

- ▶ glass
- ▶ porcelain
- ▶ paper
- ▶ dry wood
- ▶ rubber
- ▶ plastic

Electric current

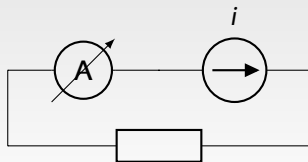
- ▶ *overall flow* of electric charges
- ▶ created by the action of electromagnetic force
- ▶ carriers : ions or (in most cases) electrons
- ▶ in electrical networks, a generator produces a *charge imbalance*
⇒ electrons move through a closed loop

Current intensity

$$i = \frac{dq}{dt}$$

By definition, $1 \text{ A} = 1 \text{ C} \cdot \text{s}^{-1}$

The current is measured using an *ammeter* connected in *series*.



Conventions

- ▶ Current can be created by positive or negative charge carriers.
- ▶ Conventional current is arbitrarily defined as a positive charges flow.
- ▶ By convention, the electrical current exits the generator through the positive (+) terminal and returns to the generator through its negative (-) terminal.
- ▶ Inside the generators, the inverse convention applies.
- ▶ *The conventional direction may differ from the actual direction of the charge carriers.*

Propagation rate

- ▶ Propagation rate of the electric current in a copper wire :
 $273000 \text{ km} \cdot \text{s}^{-1}$
- ▶ This is *not* the speed of electrons (a fraction of millimeter per second)
- ▶ *Signal is faster than matter*

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What distance does an electron travel in domestic network ?

Effects

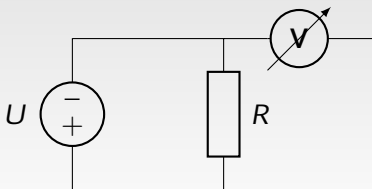
- ▶ Heating
- ▶ Chemical decomposition
- ▶ Mechanical action
- ▶ Creation of magnetic fields
- ▶ ...

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Voltage

- ▶ Voltage *between two points* = work done per unit of charge against a static electric field to move between these points.
- ▶ Voltage unit = Volt
- ▶ $1\text{ V} = 1\text{ J} \cdot \text{C}^{-1}$
- ▶ Notation U (single-phase) or V (three-phase).
- ▶ Measured with a voltmeter or an oscilloscope connected in *parallel*.



Electrical power

- ▶ Power = Energy per unit of Time
- ▶ Power unit = Watt
- ▶ $1\text{ W} = 1\text{ J}\cdot\text{s}^{-1}$ and $1\text{ J} = 1\text{ W}\cdot\text{s}$
- ▶ Power = flow of Energy
- ▶ Electrical power : $P = U \cdot I$

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Electrical resistance

- ▶ Measurement of the difficulty to pass a current through a component
- ▶ Leads to a *drop in carriers energy* when passing through the component
- ▶ Unit : Ohm
- ▶ OHM's law : $U = R \cdot I$

Power dissipation in a resistor : JOULE effect

- ▶ Conversion of *electrical energy* into *heat*.
- ▶ $P = U \cdot I$
- ▶ $P = R \cdot I^2$
- ▶ $P = \frac{U^2}{R}$

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Hydraulic Analogy

Example of a waterfall

- ▶ Electrical charge \Leftrightarrow Quantity of water
- ▶ Electrical current \Leftrightarrow Hydraulic volume flow rate
- ▶ Voltage \Leftrightarrow Hydraulic head

⚠ Fluid particles can move at variable speed

Conclusion

In this chapter we have seen...

- ▶ how electric current is created in conductive materials
- ▶ the definitions of fundamental parameters of electric current
- ▶ the main properties of resistors