EE1C1 “Linear Circuits A”

Week 1.1

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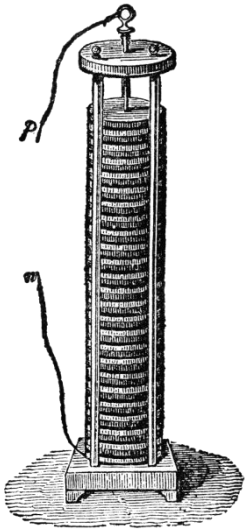
Today

- The basis:
  - principles
  - terminology
  - basic quantities
- Circuit elements: independent/dependent sources
- Resistance & Ohm's law
- Summary and conclusions
- Next tasks

The basis

The basis: principles

- A Volta pile generates a sustained electrical stimulus
- More cells ("Volts") ⟶ more "energetic" a stimulus
- Number of "Volts" = voltage
- One always needs two points for taping the energy



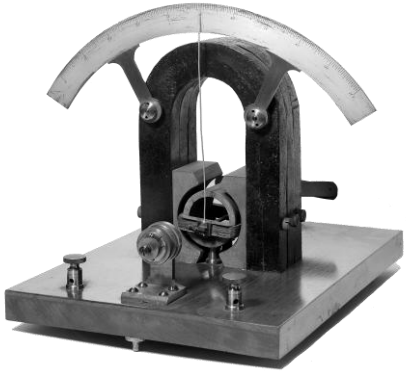
Volta pile
(1800)

Alessandro Antonio Volta
(1745–1827)

Voltage + 2 access points

The basis: principles

- An electric current deflects a magnetic needle
- A precise method for measuring electric currents
- One always needs two points for measuring a current
- Swapping the connection gives a negative measurement



Galvanometer
(1820-1850)

Hans Christian Ørsted
(1777-1851)

Electric current + 2 access points + polarity

The basis: principles

- Two basic, easily measurable ("observable") quantities: voltage + (electric) current
- Pairs of access points
  - at which the supplied energy
  - between which the current

} can be unambiguously measured (predicted)

Ports

Circuit analysis = the analysis of the relations between voltages and currents at given ports

The basis: principles

Accounting for the electric charge
= a property of matter

- Two basic, easily measurable (“observable”) quantities:
  voltage + (electric) current

Movement of electrical point charges and their energy

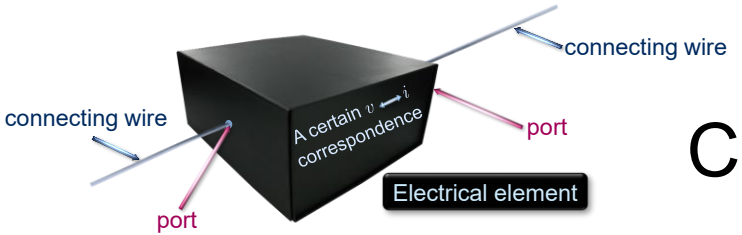
analogy with fluid dynamics (be careful, be wise)

Circuit analysis = the analysis of the relations between voltages and currents at given ports

The basis: principles

In circuit analysis we study **electric circuits**

Electrical elements (lumped elements)



+

Connecting wires

Models

More details in “Basic concepts in circuit analysis” on Brightspace

The basis: quantities, measure units

- SI standard system:
  - length ⟺ meters (m)
  - time ⟺ second (s)
  - current ⟺ ampere (A)
- Derived quantities and units:
  - charge ⟺ s·A = coulomb (C)
  - electric potential ⟺ volt (V)
  - power ⟺ watt (W)
  - energy ⟺ joule (J)

The basis: electric charge & electric current

- The charge: an electrical property of sub-atomic constituents, measured in coulomb (C)
- The charge of an electron e = -1.602 x 10^{-19}C
- The electric current: a measure of the temporal variation of the electric charge, measured in ampere (A)

equal, by definition

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

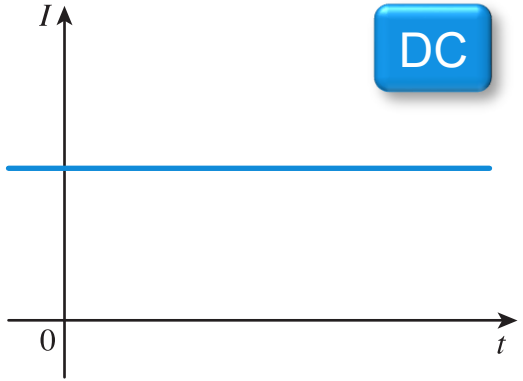
positive charges!

$$q = \int_{t_0}^{t} i\,dt + q(t_0)$$

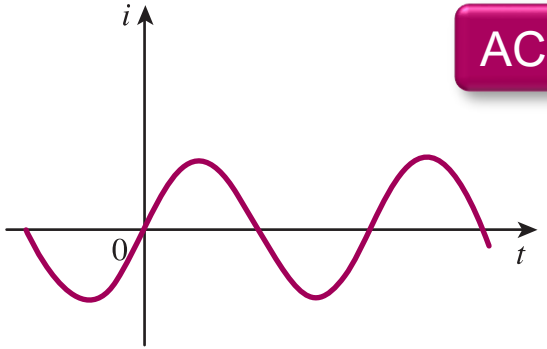
Only finite values!

The basis: electric charge & electric current

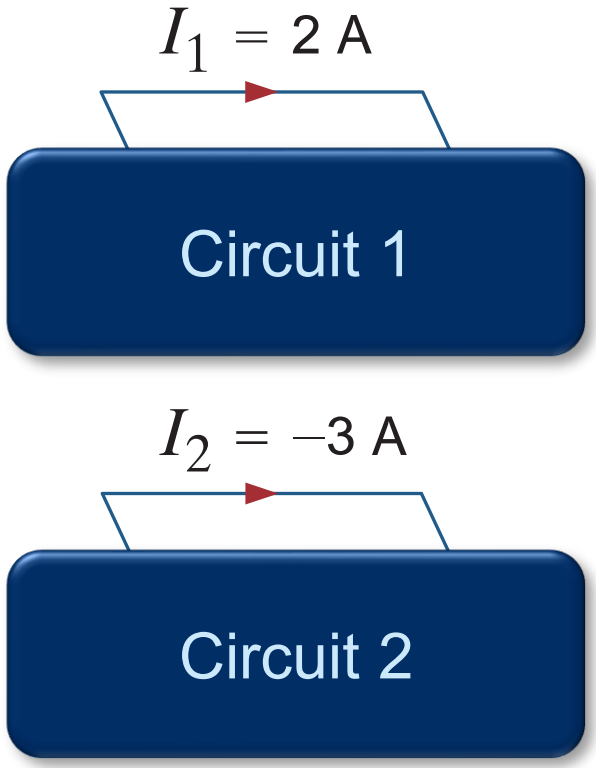
- A direct current (dc)
  is a current that remains
  constant with time



- An alternating current (ac)
  is a current that varies
  sinusoidally with time



The basis: electric current direction



A positive value for the current indicates a flow in the direction of the arrow (the reference direction)

A negative value for the current indicates a flow in the direction opposite to the reference one

The basis: electric current direction

1. The current in B flows in opposite direction as in A
2. The current in B flows in the same direction as in A
3. This notation is misleading and should never be used

The basis: electric current direction

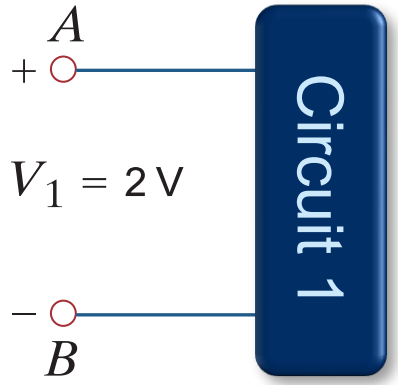
This can be a connecting wire or an electric element

The basis: potential & voltage

- The potential is the (electrical) potential energy per unit charge

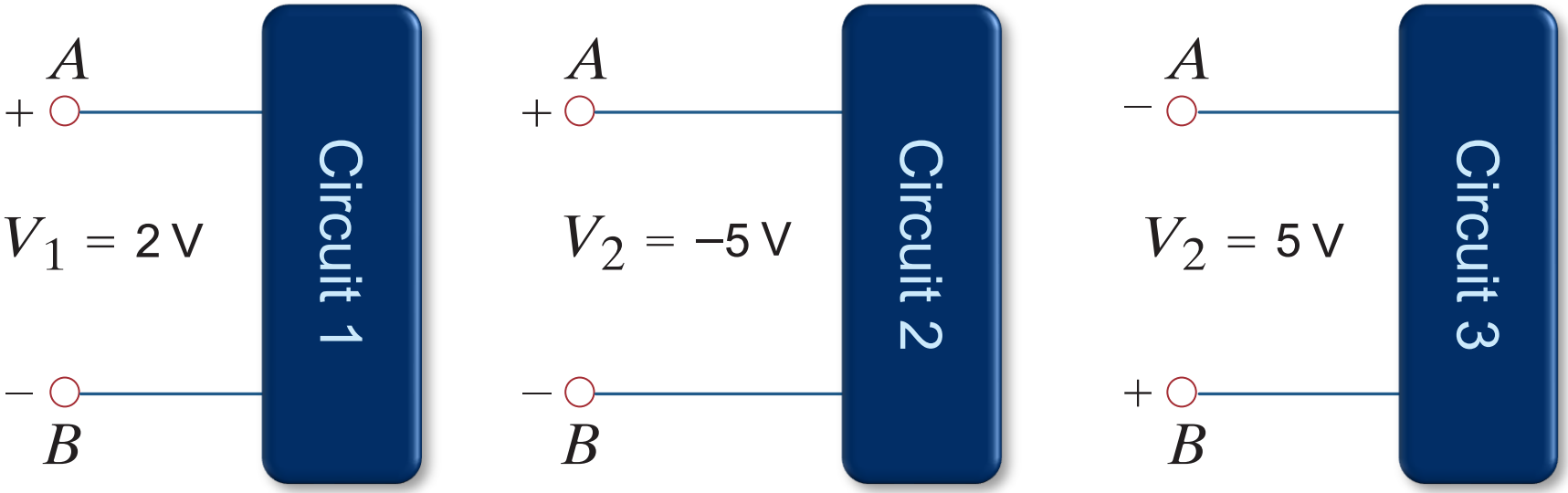
$$v_{ab} \triangleq \frac{dw}{dq}$$

- The potential difference between two points is denoted as voltage



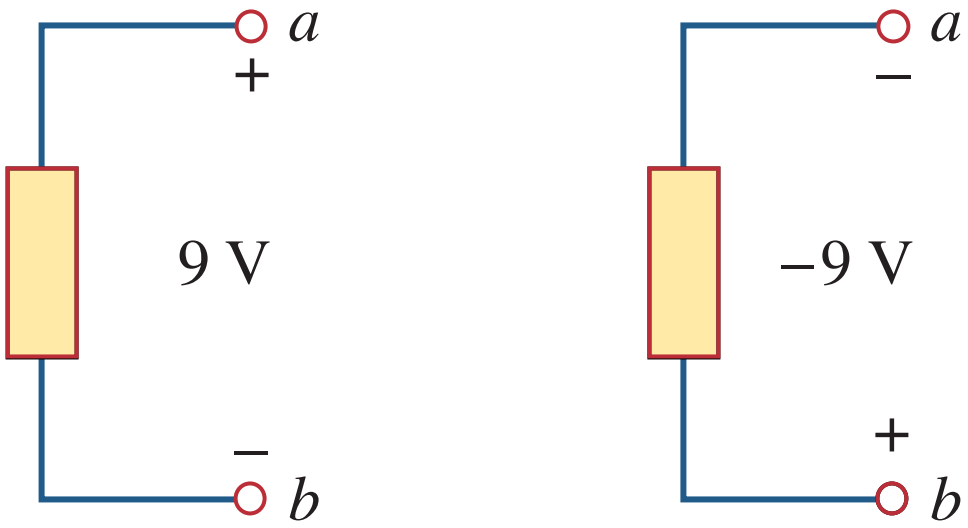
Only finite values!

The basis: voltage direction



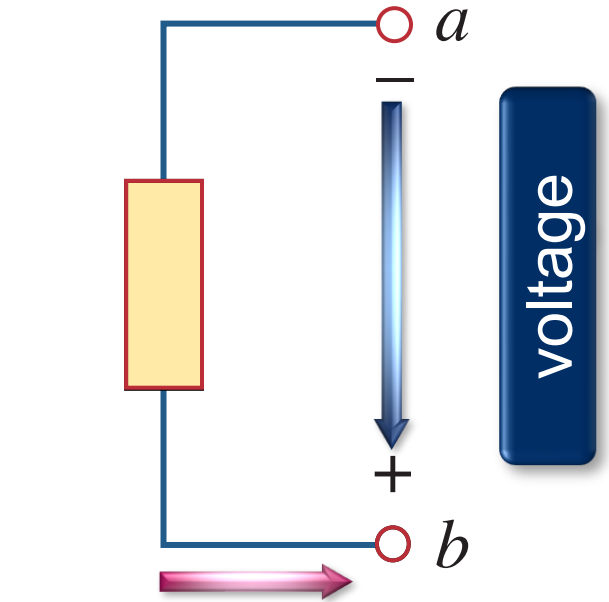
1. The voltages in circuits 1 and 3 have the same polarity
2. The voltages in circuits 1 and 3 have opposite polarities

The basis: voltage direction



This is always an electric element!

The basis: electric current & voltage

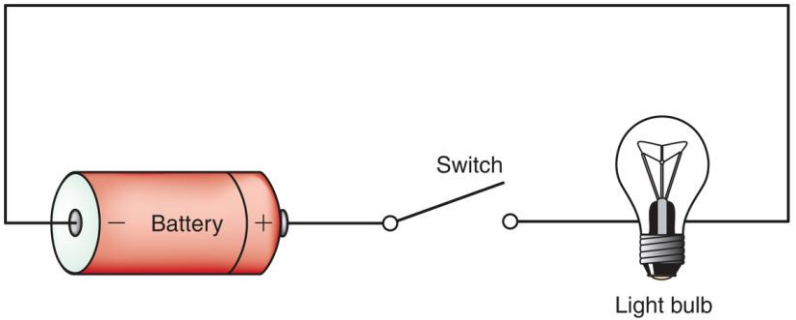


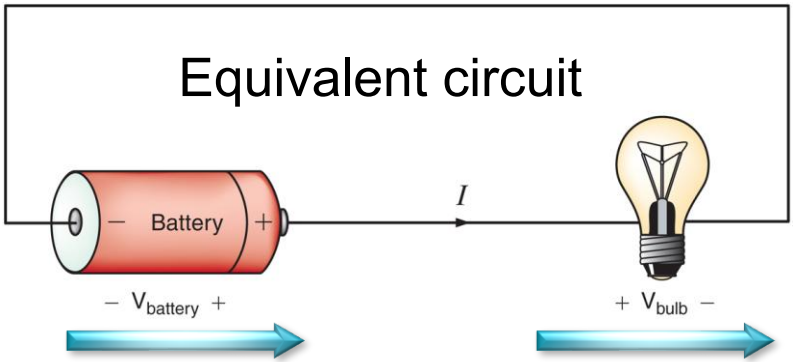
- Voltage ⟶ "across"

- Electric current ⟶ "through"

The basis: energy & power

- Energy is transformed
- Power is supplied to the lamp





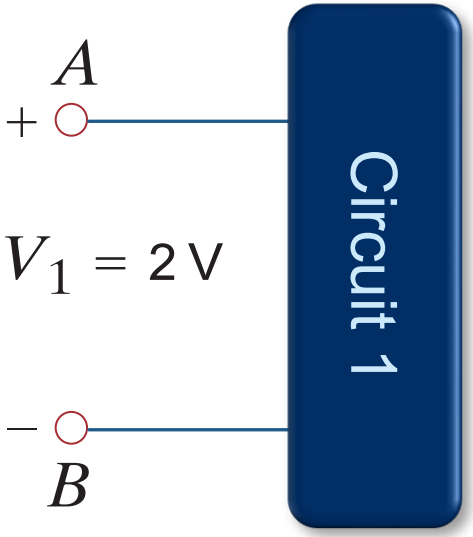
The basis: energy & power

- How much energy you need for moving 120 C from B to A?

$$v_{ab} = 2\text{V}$$

$$v_{ab} \triangleq \frac{dw}{dq} = \frac{w}{q}$$

$$w = q \cdot v_{ab} = 240\ \text{J}$$

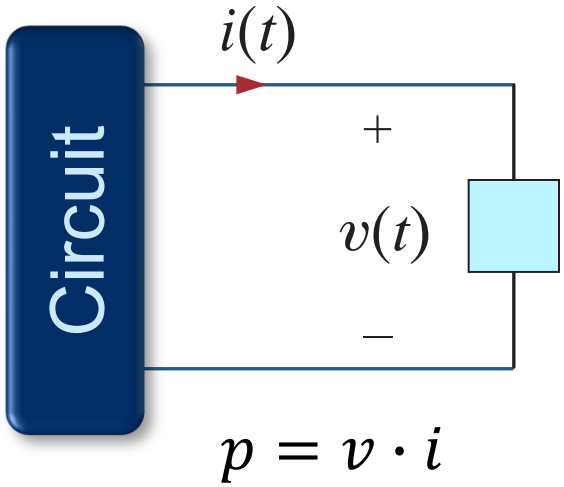


The basis: energy & power

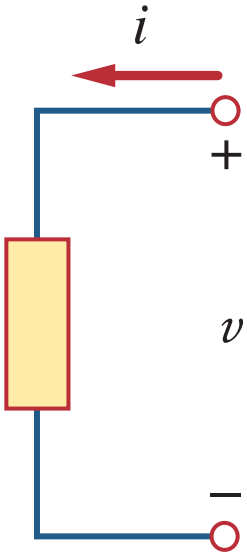
- Power = energy / time
- Instantaneous power: $p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i$
- Energy ⟶ power: $w(t) = \int_{t_0}^{t} p(t)\, dt = \int_{t_0}^{t} v(t) i(t)\, dt$

The basis: power – passive sign convention

- If the voltage and the current are both positive, then the positive charges move from a higher potential to a lower potential
- The component absorbs power
- Such an element is referred to as “passive”

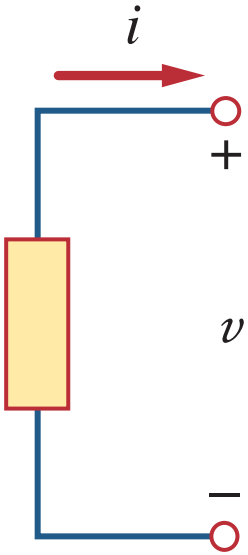


The basis: power – passive sign convention



$p = +vi$

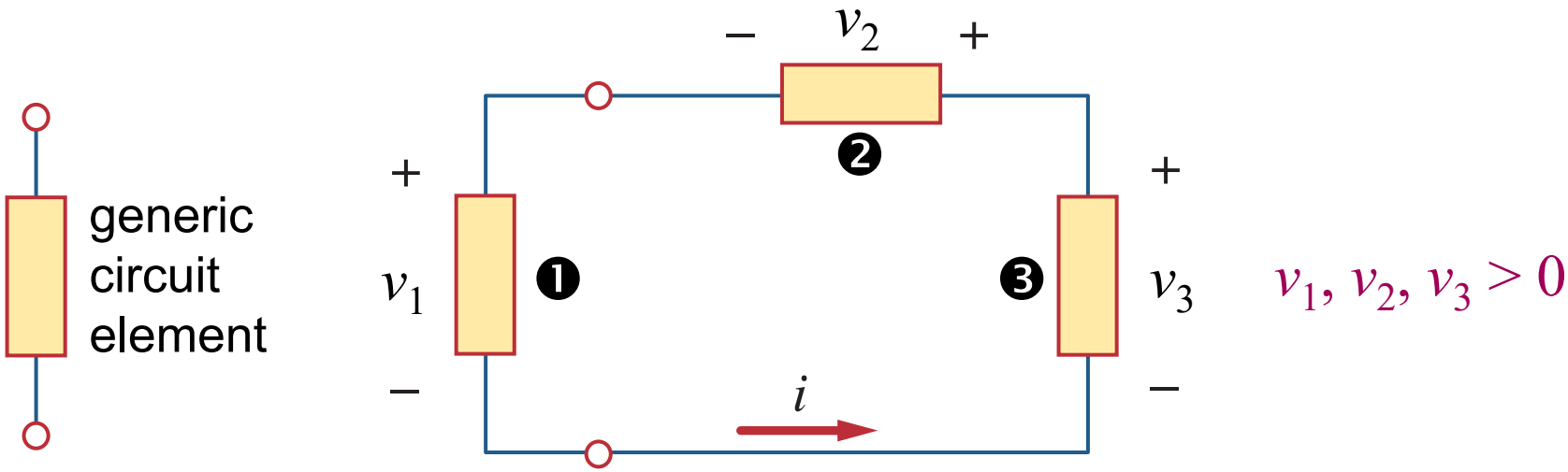
Power is absorbed



$p = -vi$

Power is supplied

The basis: power – passive sign convention

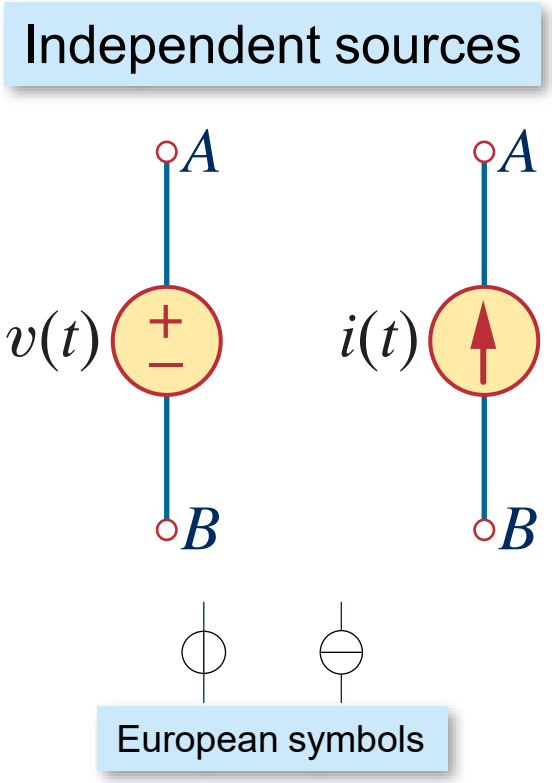


1. Element ❷ absorbs the power supplied by element ❶
2. Element ❸ absorbs the power supplied by element ❶
3. None of the above

Circuit elements

Circuit elements: independent sources

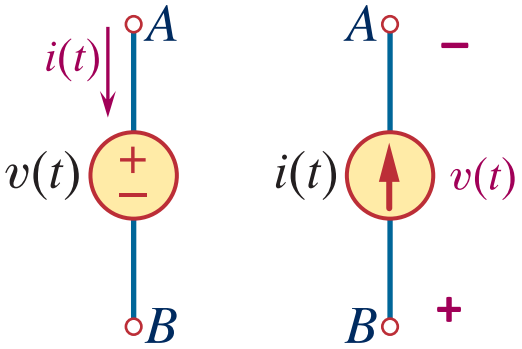
- The voltage / current supplied by the source is independent of the voltage across / the current through it
- Ideal situation
- Ideal sources can supply infinite power
- A socket can be construed as a voltage source



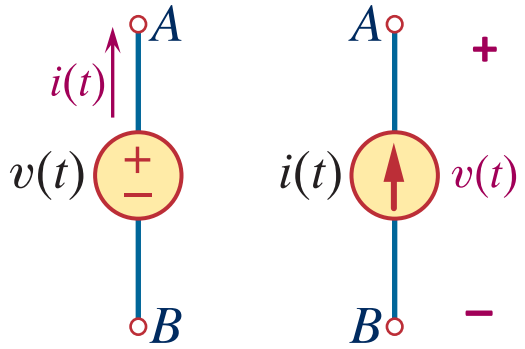
Circuit elements: independent sources

- Passive sign convention revisited:

Positive power: $p = iv$



Negative power: $p = -iv$

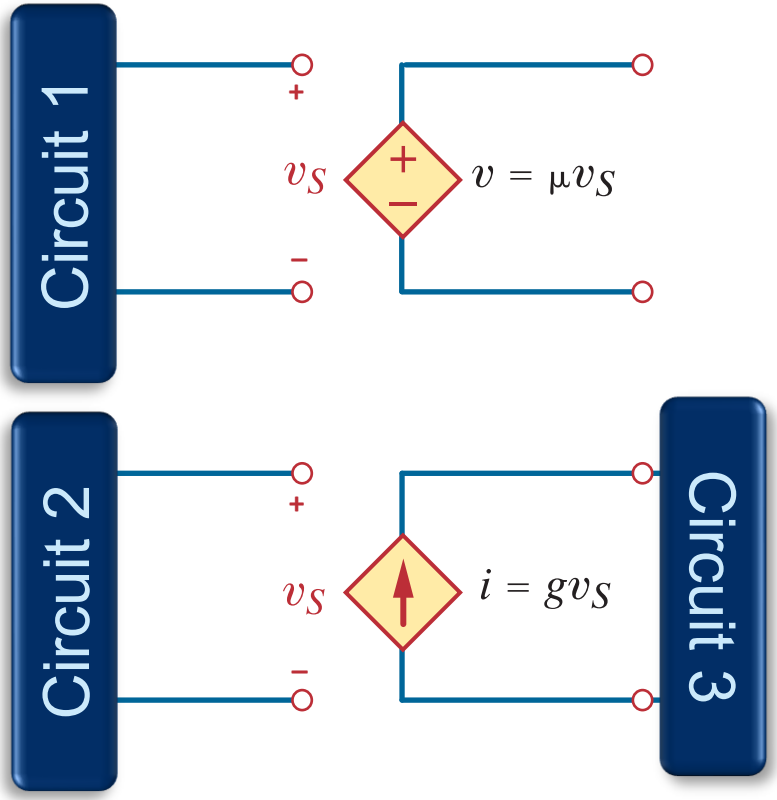


- Summarising:
  - positive power ⟶ absorbed power ⟶ the device is ‘driven’
  - negative power ⟶ supplied power ⟶ the device ‘drives’

Circuit elements: voltage-controlled sources

- The voltage or current supplied by the source depends on the voltage between the source's controlling terminals v_S

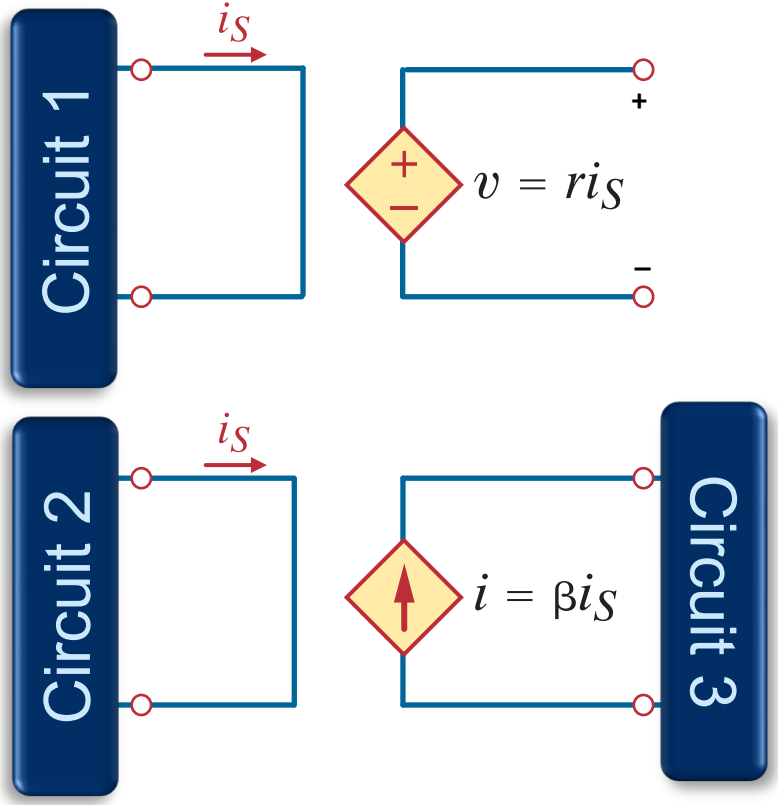
- Attention: the two circuits are electrically disjoint!



Circuit elements: current-controlled sources

- The voltage or current supplied by the source depends on the current flowing between the source's controlling terminals i_S

- Attention: the two circuits are electrically disjoint!



Resistance & Ohm’s law

Resistance & Ohm's law

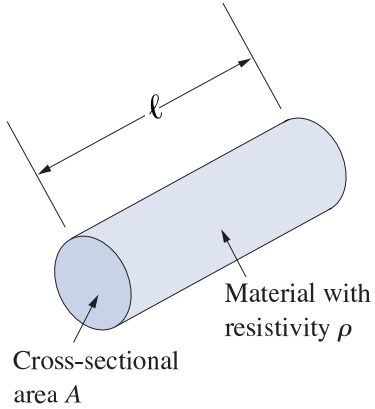
- Resistance = the ratio $v(t)/i(t)$ at the same instant t
- Historically: Ohm's law (1827)

$$R = \frac{v}{i}$$

  - established in DC
  - R is measured in ohms (Ω)
- Resistance: interpreted as an element's ability to resist the flow of electric current

Georg Simon Ohm
(1789–1854)

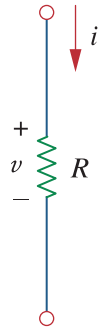
Resistance & Ohm's law



- For wire-like conductors: $R = \rho \frac{\ell}{A}$
  - ρ = resistivity
  - ℓ = length of the wire
  - A = cross-sectional area (uniform current distribution)

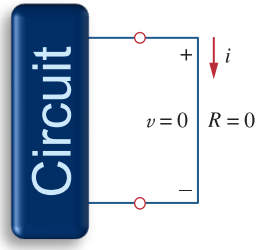
Material	Resistivity (Ω·m)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Silicon	6.4×10^{2}	Semiconductor
Teflon	3×10^{12}	Insulator

Symbol:

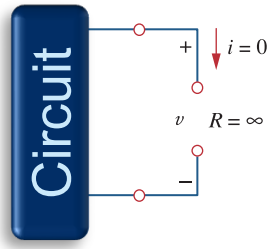


Resistance – particular situations

- Short circuit = a circuit element across which the voltage is zero for any finite current
  - book: a circuit element with resistance approaching zero $\longrightarrow v = iR = 0$



- Open circuit = a part of the circuit through which the current is zero (for any finite voltage)
  - book: a circuit element with resistance approaching infinity $\longrightarrow i = \lim_{R \to \infty} \frac{v}{R} = 0$



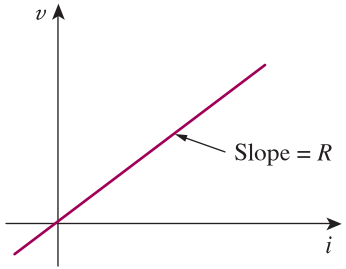
Resistance – derived quantities

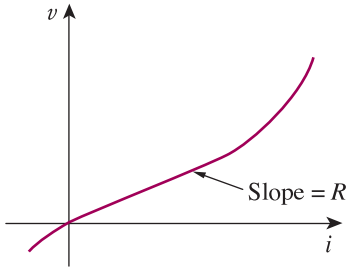
- Conductance = reciprocal of resistance

$$G = \frac{1}{R} = \frac{i}{v}$$

  - it is measured in siemens (S)

- Nonlinear resistance





Summary of the day

- The basic concepts in electric circuits:
  voltage, current ⟶ charge, energy, power
- Independent / dependent sources
- Resistance & Ohm's law
- These concepts & elements will be heavily used in the coming weeks for:
  - circuit analysis
  - circuit design

Next tasks

- Next week the lecture will be given by Francesco
  - Monday, September 9: Chapter 2 (continued)
- This week:
  - seminars tomorrow and on Friday
- Don’t forget to register on MS Teams

- For your attendance
- For reviewing this lecture
- For reading the book's chapter
- For participating in the week's seminars