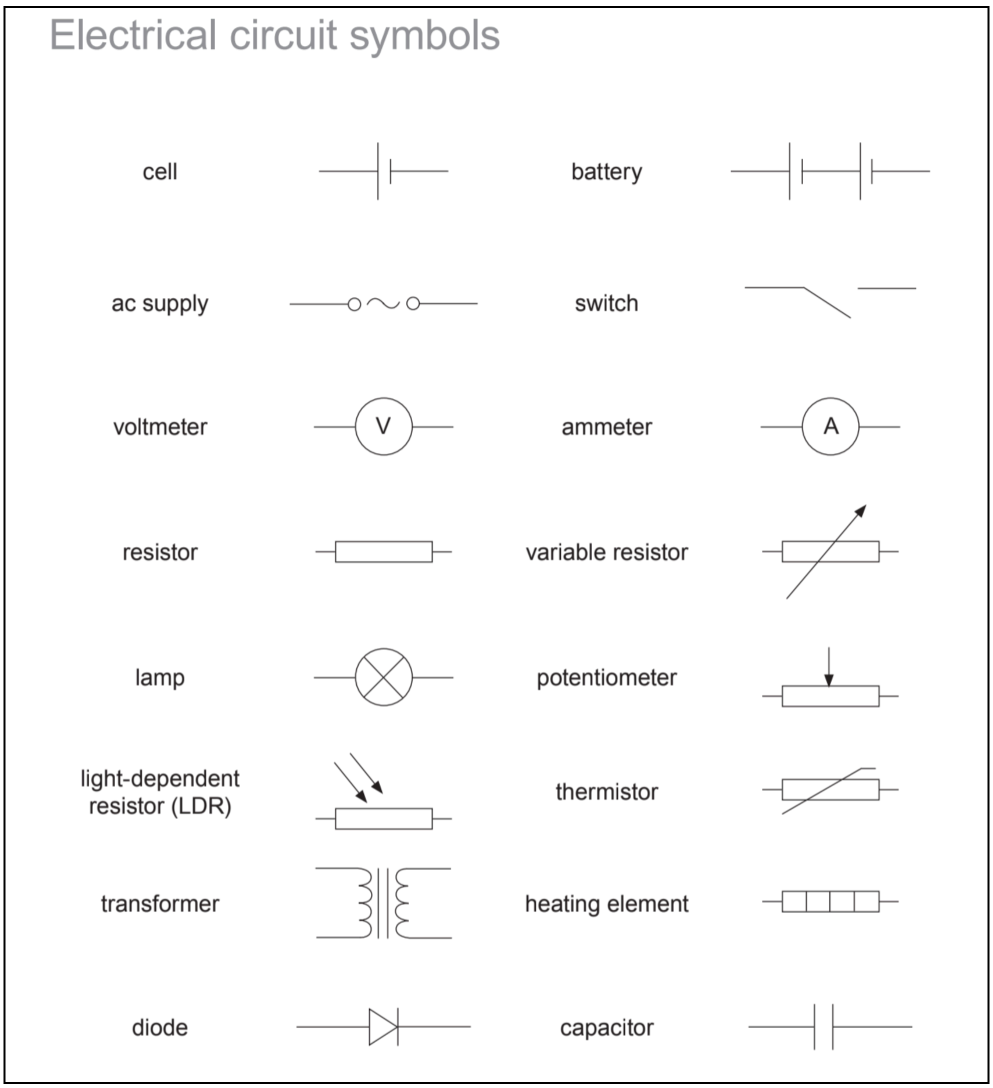
Electric circuits

- Electric circuits
- Heating effect of electric currents

Electric circuits

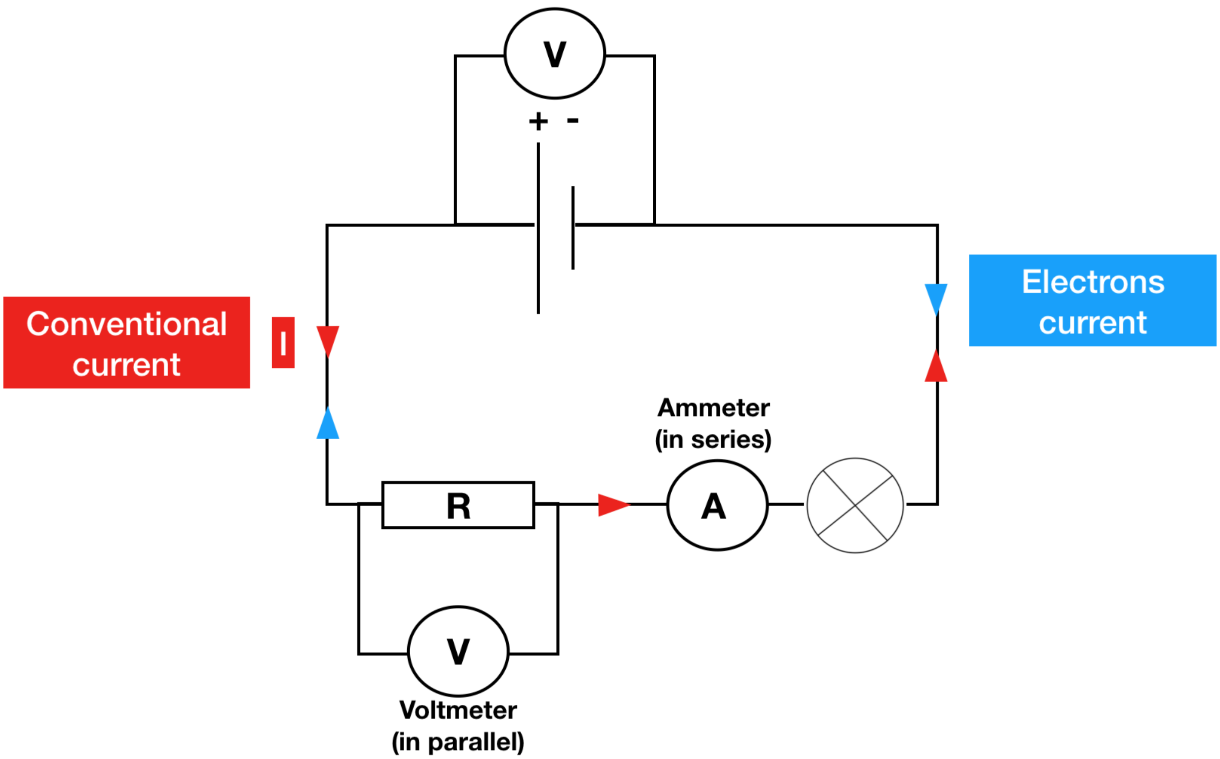


We will have 2 different types of electric circuits:

- Circuits in parallel
- Circuits in series

An electric circuit must contain a generator (cell or battery) and receptors (lamps/motors/resistors…).

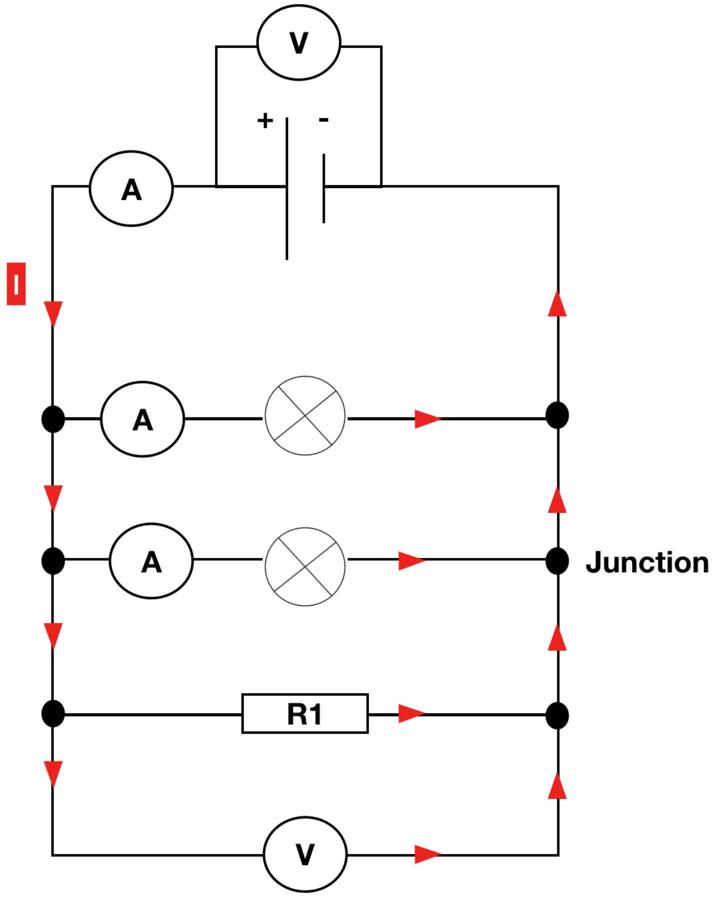
Circuit in series:



For circuit in series:
The current is the same in every part of the circuit.

Kirchhoff's laws for voltage:
The voltage of the generator (p.d.) is equal to the sum of the voltages of the different receptors in series

Circuit in parallel:



For circuit in parallel:
The voltage is the same for every devices connected in parallel

Kirchhoff's laws for current:
The sum of the currents entering a junction is equal to the sum of the current leaving the junction

- The current is measured by an ammeter. The ammeter is connected in series in a circuit. An ideal ammeter has zero resistance

- The voltage is measured by a voltmeter. The voltmeter is connected in parallel to a device. An ideal voltmeter has an infinite resistance. No current enters inside the voltmeter.

The conventional current flows from the + (high electric potential) to the - (lower electric potential)
The electrons current flows from the - to the +

Heating effect of electric currents - Electric resistance

Every conductor has an electric resistance R.

- When the electrons are accelerated by the electric field inside a conductor, they suffer inelastic collisions with the metal atoms of the conductor which means that they lose kinetic energy.
- This energy is gained by the atoms of the conductor.
- They start vibrating and this vibration is transformed into thermal energy.
- The conductors get hot.

The electric resistance R of a conductor is defined as the potential difference V across its ends divided by the current I passing through it:

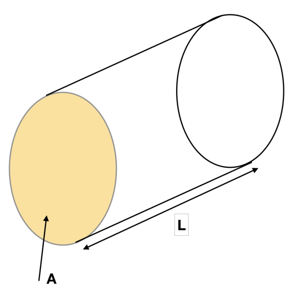
$$R = \frac{V}{I}$$

R is in Ohm (Ω), V in volt and I in A

The resistance of a conductor is also defined by the following formula:

$$R = \frac{\rho L}{A}$$

A is the cross-section area of the wire.
ρ is called resistivity (in Ω.m) and depends on the material of the conductor and the temperature. L is the length of the conductor.

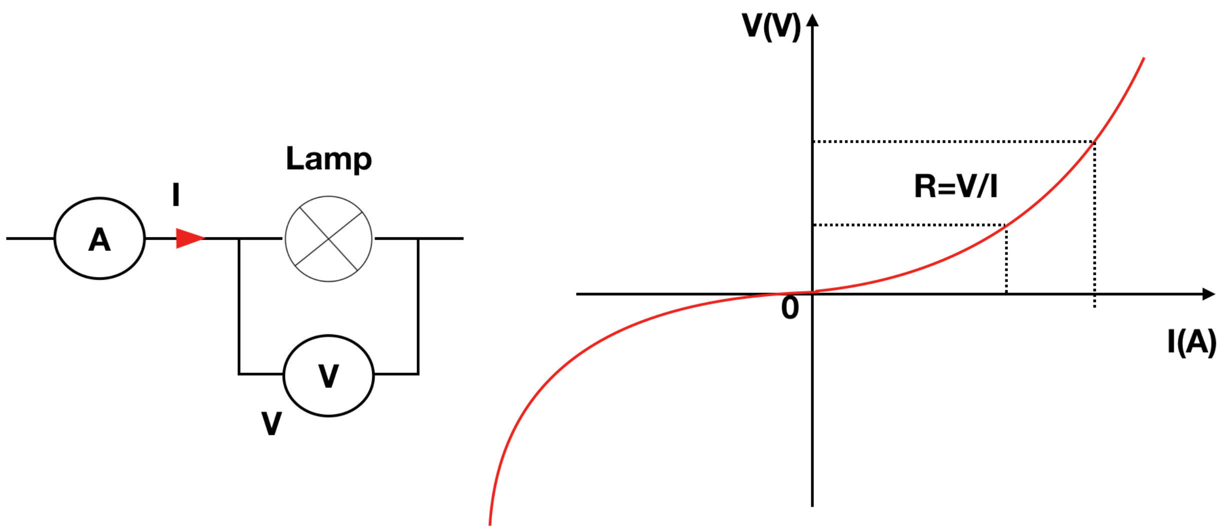


Exercise 5

The resistivity of copper is 1.68 x 10-8 Ω.m. Calculate the length of copper wire of diameter 4.00 mm that has a resistance of 5.00 Ω.

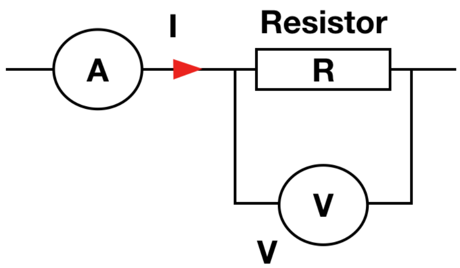
Graph Voltage-Current for different elements of the circuit

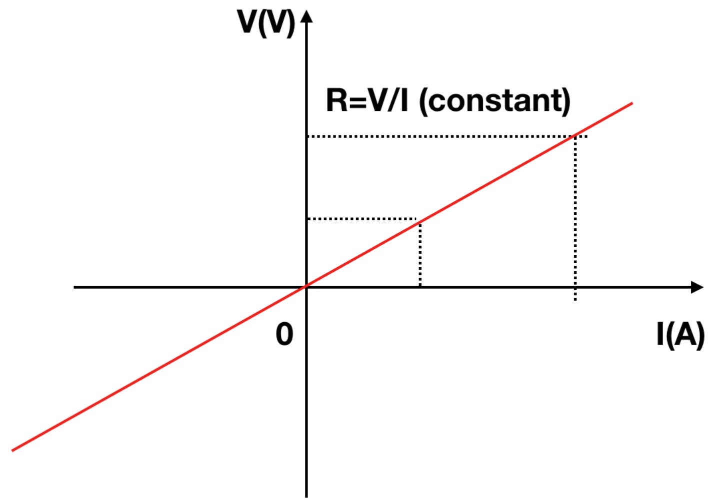
- Graph VoltageCurrent for a lamp



We can see that the resistance of the lamp is not constant.
When I is increasing, R increases as well.
When the current is increasing, the temperature of the lamp is increasing as well. The atoms vibrate more, increasing the interaction with the electrons. Therefore the resistance is increasing.

- Graph Voltage-current for a resistor R - Ohm's law





For a resistor, the resistance is constant. The temperature does not affect the value of the resistance. The resistor is called an ohmic conductor.

Ohm's law states that V and I are proportional

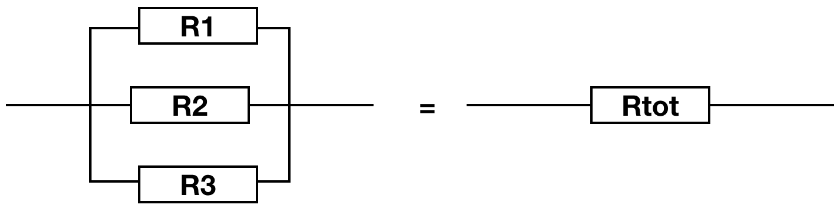
A conductor is said to be ohmic if its resistance remains constant (the U / I ratio is constant) and does not depend on temperature.

Resistors in series

$R_{tot} = R_1 + R_2 + R_3 + \ldots..$

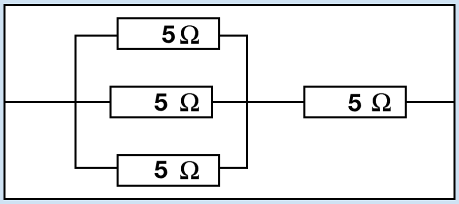
Resistors in parallel

$$\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$



Exercise 6

Calculate the equivalent resistance.



Electric power - Electric energy

- The power P is in Watt:

  $P = V.I$ with V in volt and I in A.

- This power manifests itself in thermal energy

  $P = (R.I).I = R.I^2 = V^2/R$

- This is called the Joule's effect.

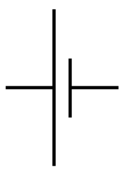
  The Joule effect is the power (energy) dissipated. The energy that is given to the environment outside.

- Relation between power and energy

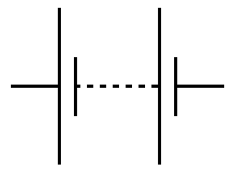
  $P = E.t$ with E in Joules and t in second

Cells and batteries

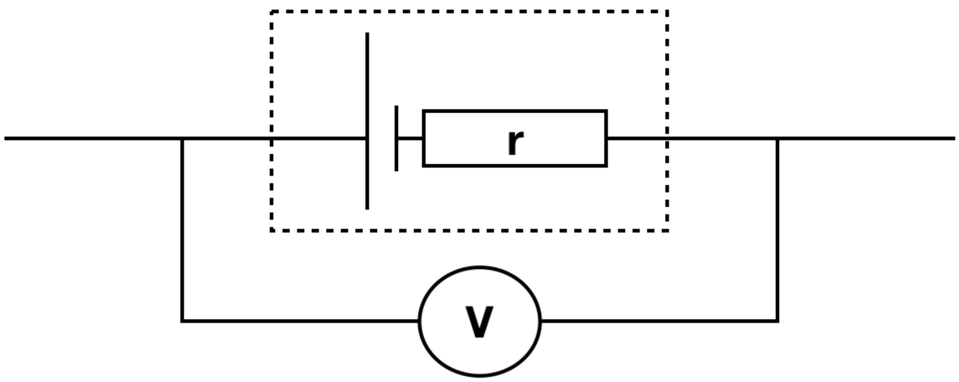
Cell



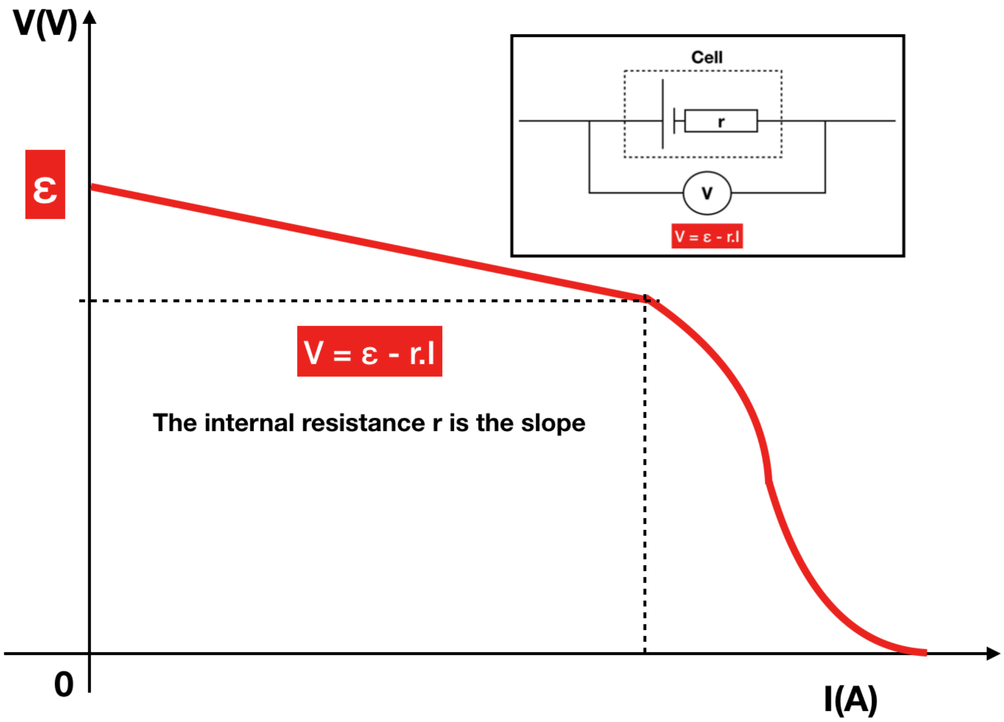
Battery



Cell



$$V = \varepsilon - r.I$$



Electromotive force (emf) ε of a battery
Work (energy) per unit of charge to move a positive charge test from the terminal negative from the battery to the positive terminal.
The emf is in V.
This is the maximum cell/battery voltage when no current is flowing in the circuit.

Internal resistance of a battery.
It is a resistance produced by the chemical components of the battery. It prevents converting all chemical energy into electrical energy.

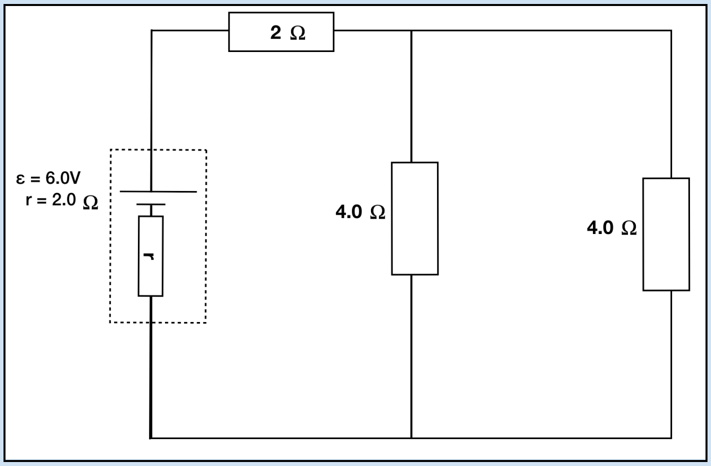
For a cell or a battery we can write: $\mathbf{V = \varepsilon - r.I}$

If we have an ideal cell/battery, there is no internal resistance r and $\mathbf{V = \varepsilon}$

Exercise 6

The potential difference across the terminals of a battery is 4.8 V when the current is 1.2 A and 4.4 V when the current is 1.4 A. Determine the emf of the battery and the internal resistance

Exercise 7



Calculate the current in, and potential difference across, each resistor in the circuit shown in the diagram