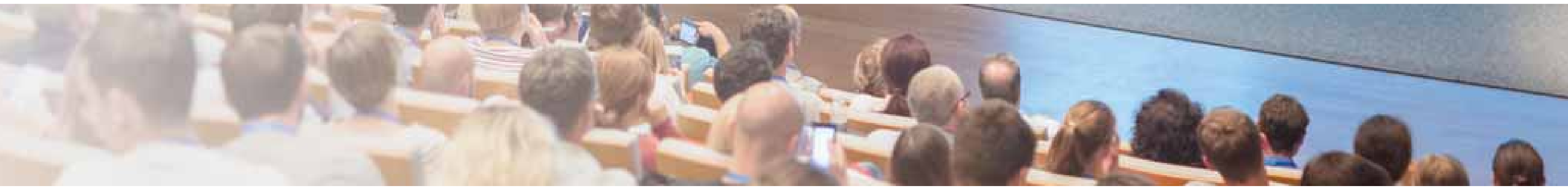


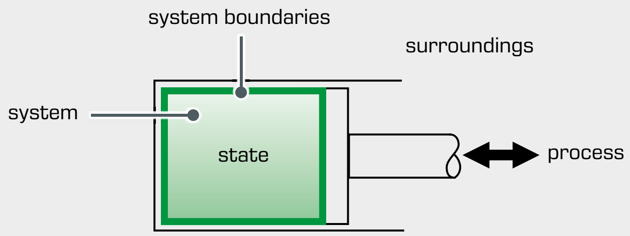
Basic knowledge

Fundamentals of thermodynamics

Thermodynamics is the general theory of energy and material transformation processes: Work is performed by redistributing energy between its different manifestations. The fundamentals of thermodynamics were developed from the study of volume, pressure, and temperature in steam engines. The following topics are selected based on the devices listed in this chapter.

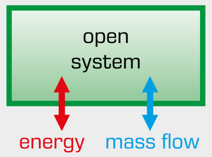
Thermodynamic systems and principles

- **system:** area of the thermodynamic examination
- **surroundings:** area outside the system
- **system boundaries:** separation of the system from its surroundings
- **process:** external impacts on the system
- **state:** collectivity of measurable properties within the system
- **state variables:** all measurable properties of the system that can be used to describe its state
- **change of state:** effect a process has on the state



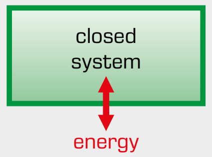
Open system

Energy or mass can be exchanged with the surroundings outside the system boundaries



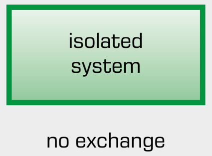
Closed system

No mass crosses the system boundary



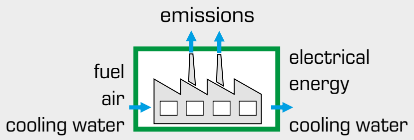
Isolated system

Neither mass nor energy cross the system boundaries



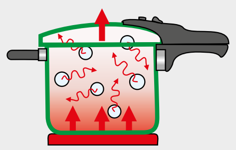
Energy transfer in the form of heat or work has the following effects in the three systems:

The energy content of the mass flow changes



Example: thermal power plant

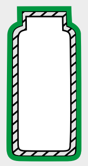
The internal system energy increases



Example: pressure cooker

The energy is constant

Thermodynamic energy conversion can take place inside the system.



Example: an ideal thermos flask

Thermodynamic laws

1st law of thermodynamics

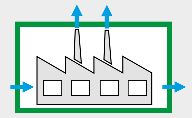
Conservation of energy in thermodynamic systems

Energy can neither be created nor destroyed, it can only be transformed.

The meaning for the three systems is illustrated in the lower left corner.

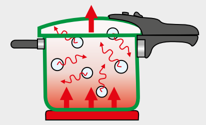
Open system

The energy content of the **mass flow** changes



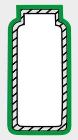
Closed system

The **internal energy** changes



Isolated system

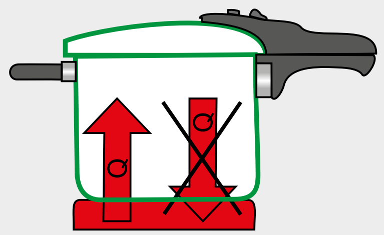
The **energy** is constant



2nd law of thermodynamics

All natural and technical processes are irreversible.

The second law places a limitation on the first law because, in reality, some energy will dissipate into the surroundings during every process. This energy can neither be used nor transformed back.



Referring to the example of the pressure cooker:

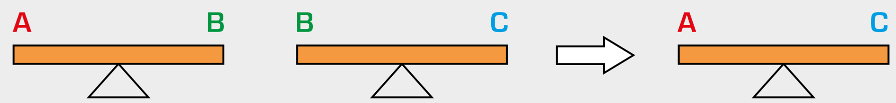
after the inside of the cooker has warmed up, the heat in the cooker cannot flow back into the heating plate.

3rd law of thermodynamics = Nernst heat theorem

The absolute zero point of 0 Kelvin is a theoretical quantity. It cannot be achieved in practice. The lowest temperature achieved to date is $2 \cdot 10^{-5}$ K.

Zeroth law of thermodynamics = law of thermal equilibrium

System A is in thermal equilibrium with system B. System B is in thermal equilibrium with system C. This means that the two systems A and C must also be in thermal equilibrium with each other.



Chronologically, the zeroth law was only formulated after the other three. Since it is fundamental to thermodynamics, it was prepended to the other three laws. This law was therefore designated as 'zeroth' to avoid having to change the names of the laws that had already been assigned.