Thermodynamica 1

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college 1 – boek hoofdstuk 1

Delft University of Technology

Course Basics

- **Lectures:** Tuesday & Friday, 10.45-12.30, lecture hall A (B & C)
- **Exercises**: Wednesday, 15:45-17:30, lecture hall A,B and C.
- **Instructors:**
  - prof.dr.ir. B.J. Boersma, tel 87979, b.j.boersma@tudelft.nl
  - dr.ir. W. de Jong, tel 89476, w.de.jong@tudelft.nl
  - prof. dr.ir. T.J.H. Vlugt , tel 87551, t.j.h.vlugt@tudelft.nl
  - ir. T. Woudstra, tel 86999, t.woudstra@tudelft.nl
- **Materials for study:**
  - Book: Moran & Shapiro, *Fundamentals of Engineering Thermodynamics 5th or 6th edition.*
  - Formula sheet (can be used at examination)
- **Exam:** written exam: 10-15 multiple choice and 2 (or 3) open questions
- See **Blackboard** for detailed information

TUDelft

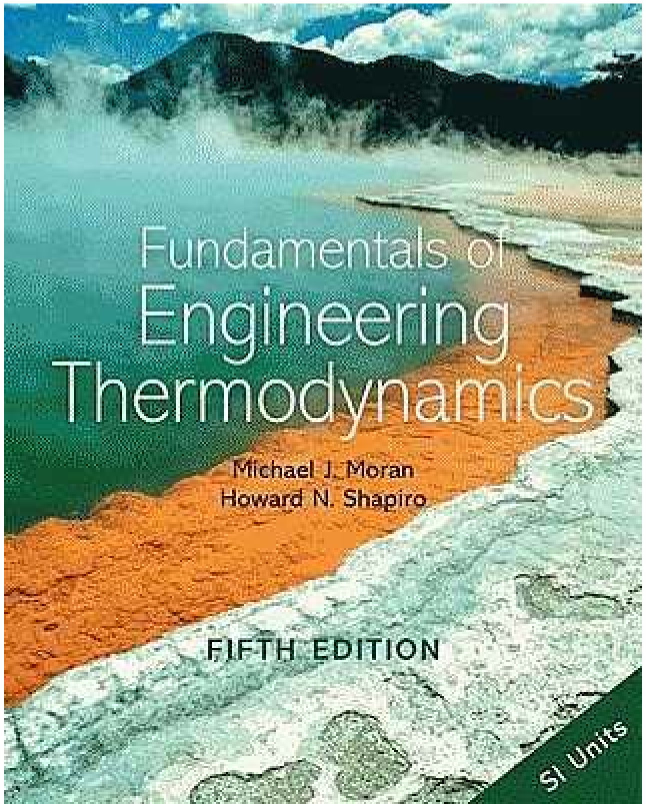
Coarse basics (contd.)

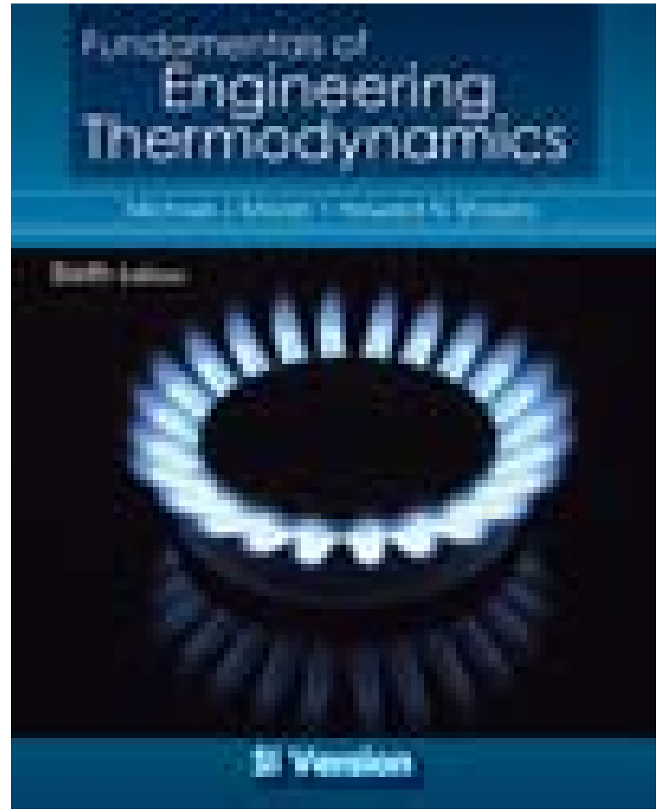
Wednesday:

- Exercises from Moran and Shapiro (see blackboard for the specific exercises)
- We expect that you try to solve the problems before the Wednesday lecture.
- The solutions of the problems will NOT be available via blackboard or collegerama.

Book: Leeghwater!!

5de of 6de editie





Boek wordt ook gebruikt voor thermo II

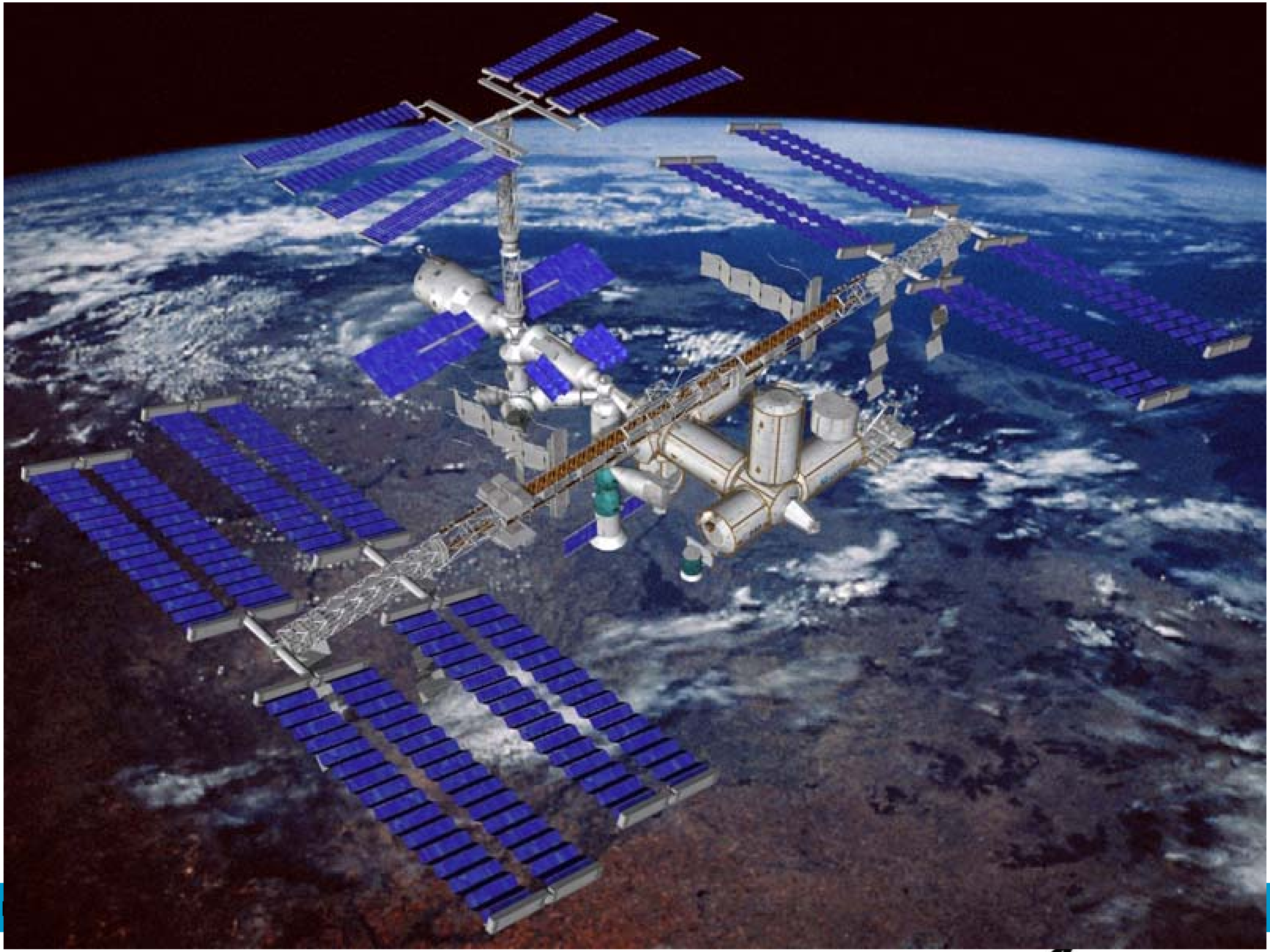
Introduction

WHAT IS A

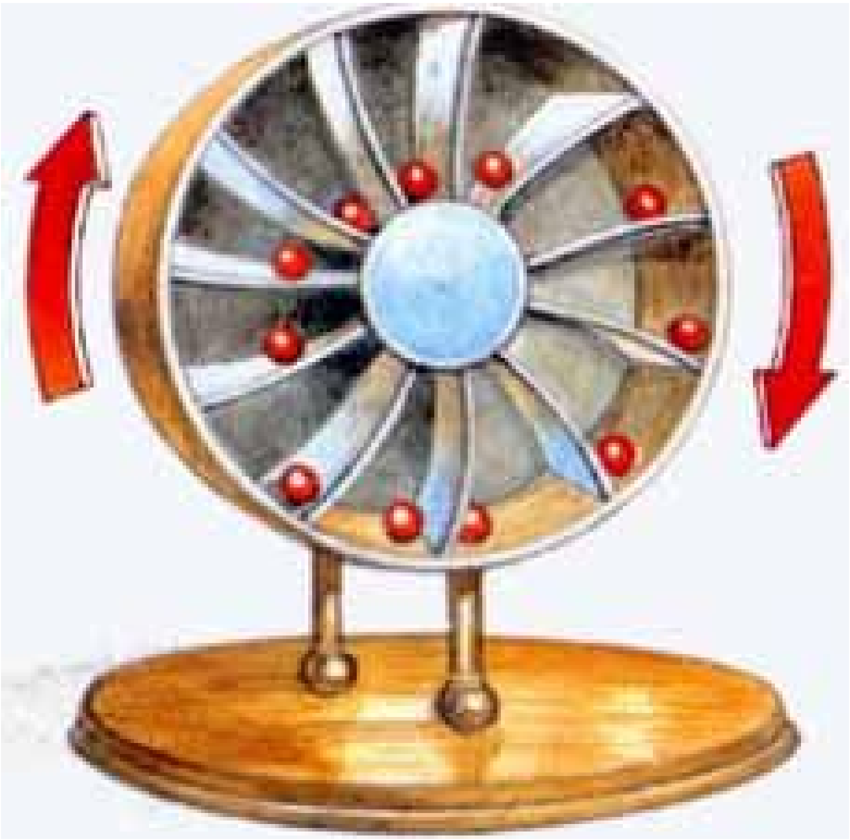
MACHINE?


DURACELL ULTRA
DURACELL


DURACELL
ULTRA
DURACELL



Perpetium mobile?



Introduction (contd.)

- ***Thermodynamics*** literally means “heat-force”

- Thermodynamics as a science started in the early 19th century to investigate the most efficient means of converting heat into work

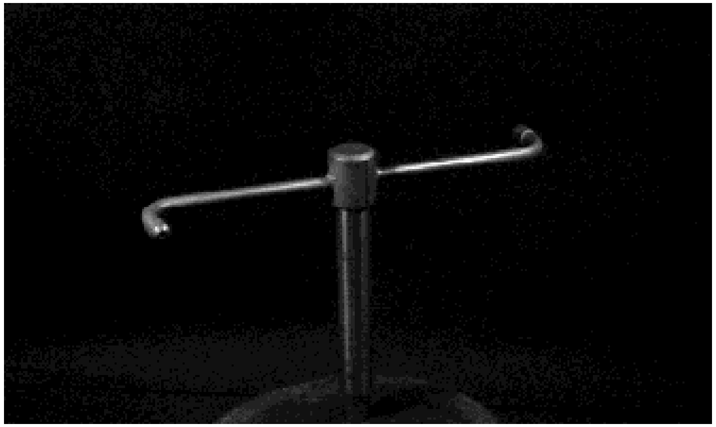
- Today thermodynamics has a more wider interpretation:
  science of (changes in) material properties in which transfer and conversion of energy by heat and work play a dominant role

- Thermodynamics is applied in: physics, chemistry, biology, material science, and engineering

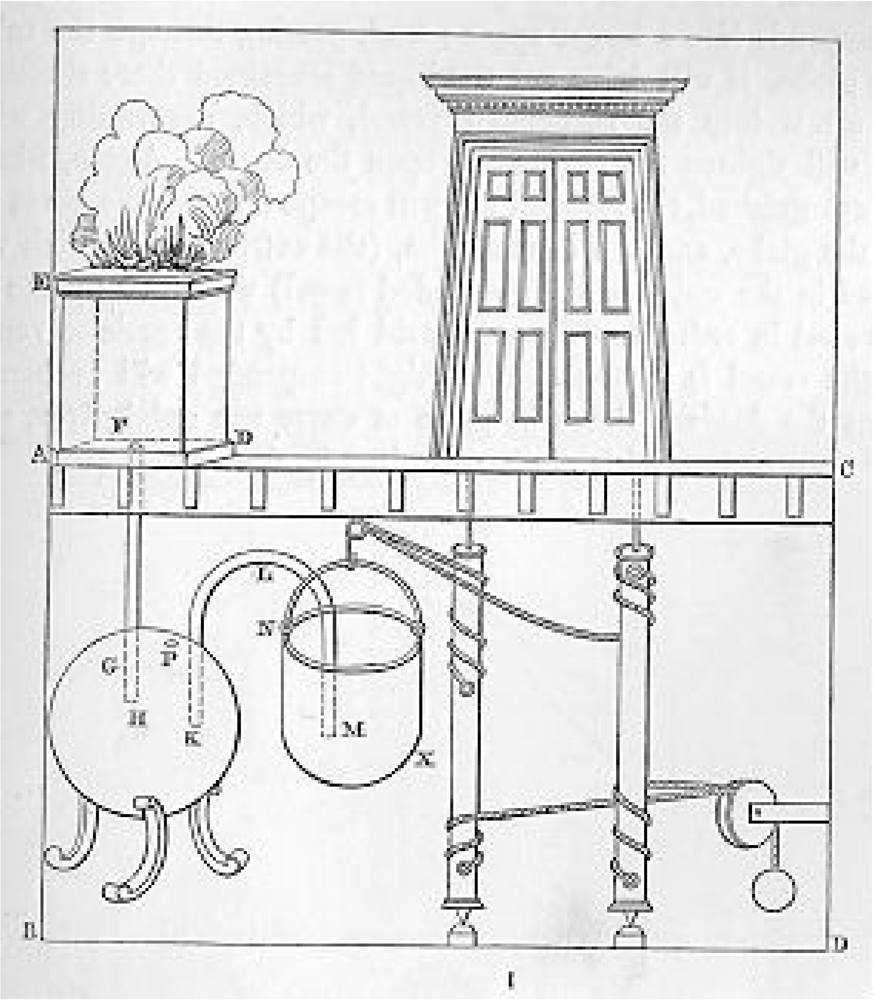
- Thermodynamics in mechanical engineering:
  (design of) heat engines

concise history (0)

- ~50:
  Hero's Aeolipile (yes, it always starts with a Greek...)



fire-powered self-opening doors



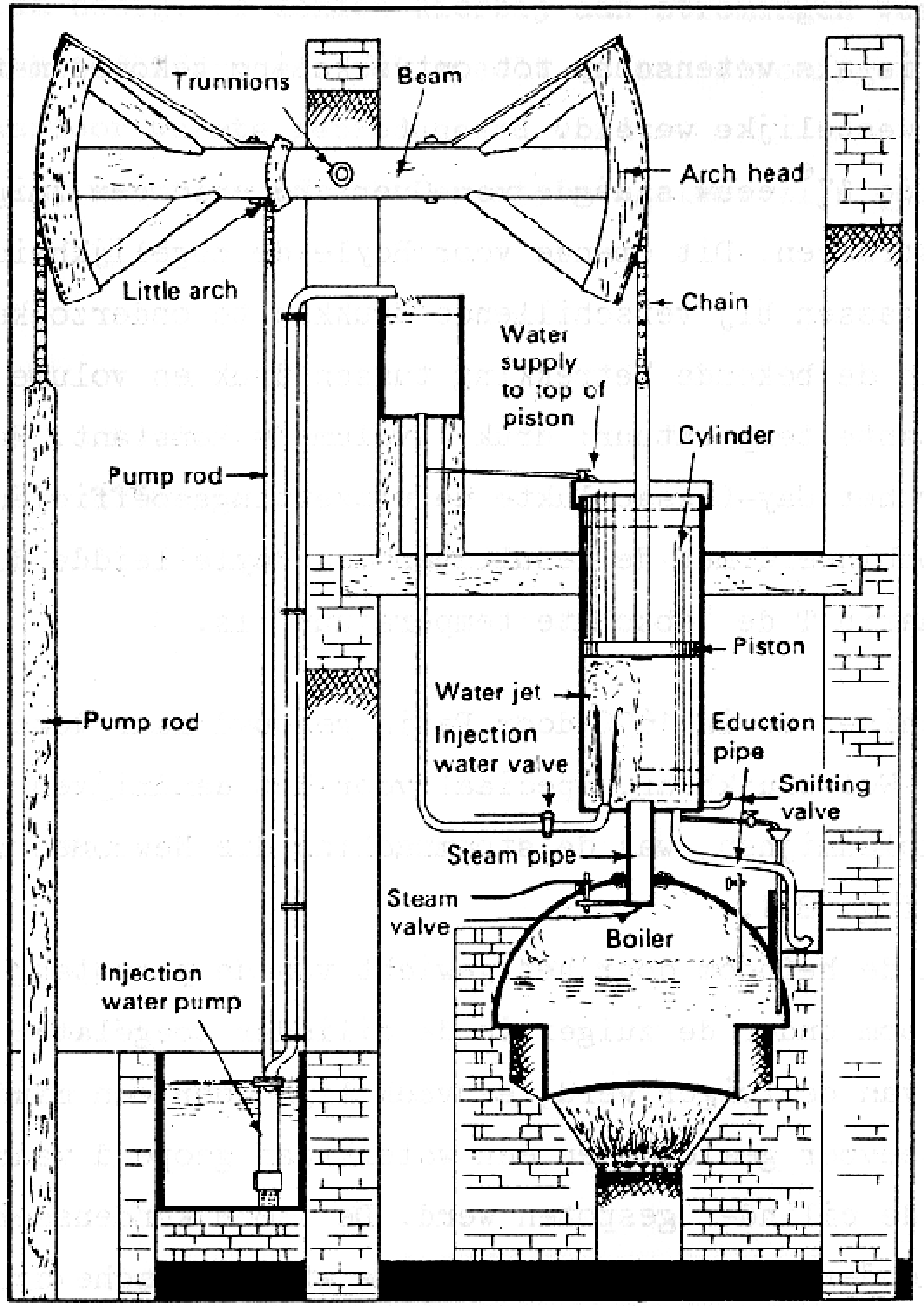
concise history (I)

- Development of thermodynamics coincides with industrial revolution
- Around 1650:
  Von Guericke: air pump
  Boyle: gas law (pV = const.)
- Around 1800:
  Gay-Lussac: $pV = RT$
- 1690:
  Papin: first steam engine (impracticable)
- 1712:
  Newcomen: first working steam engine

Balans stoommachine
Geen vliegwiel!

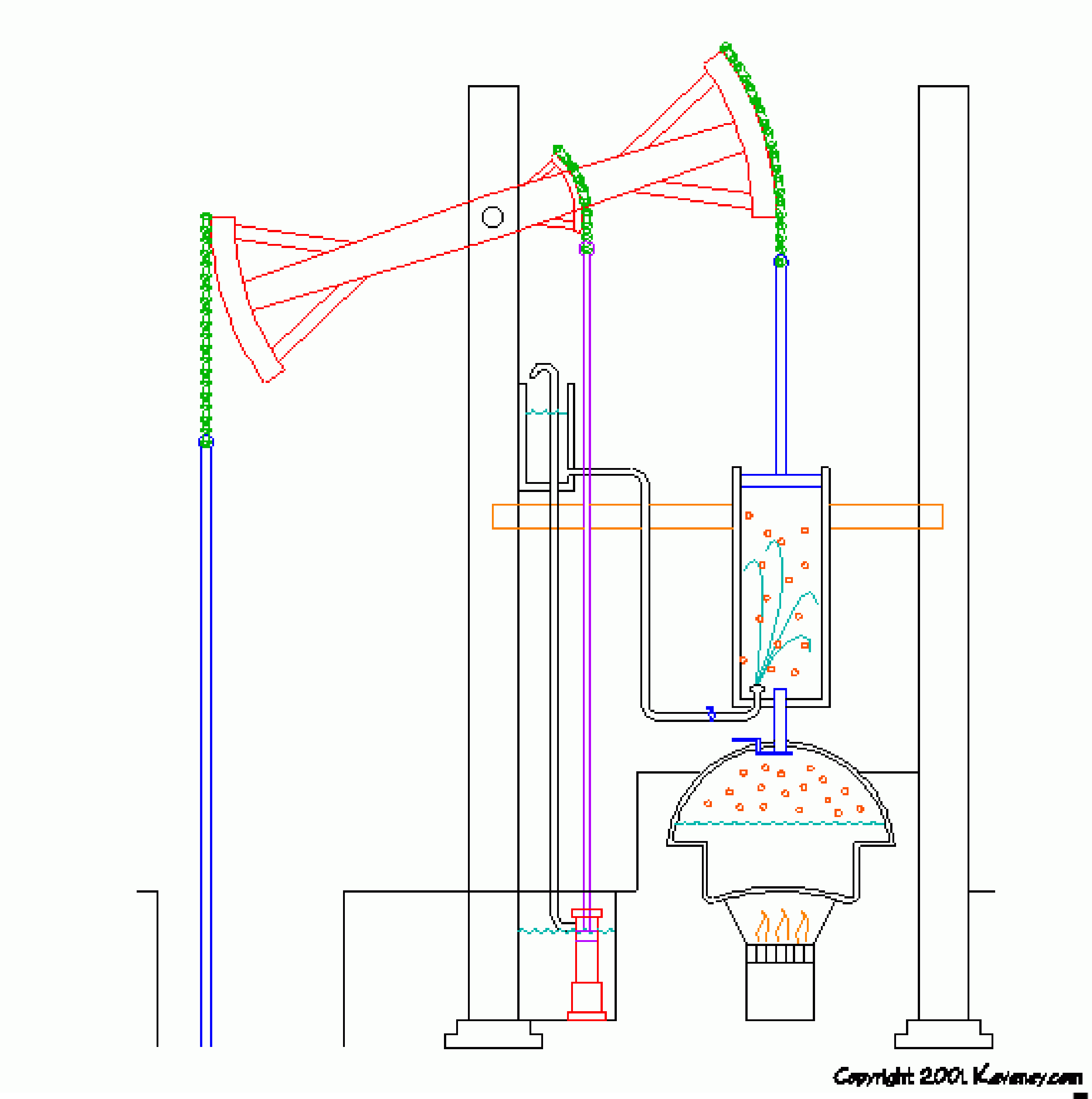
Verschil in kracht op / neer

Werkt op onderdruk!!



First working steam engine by Newcomen in 1712

Newcomben steam engine



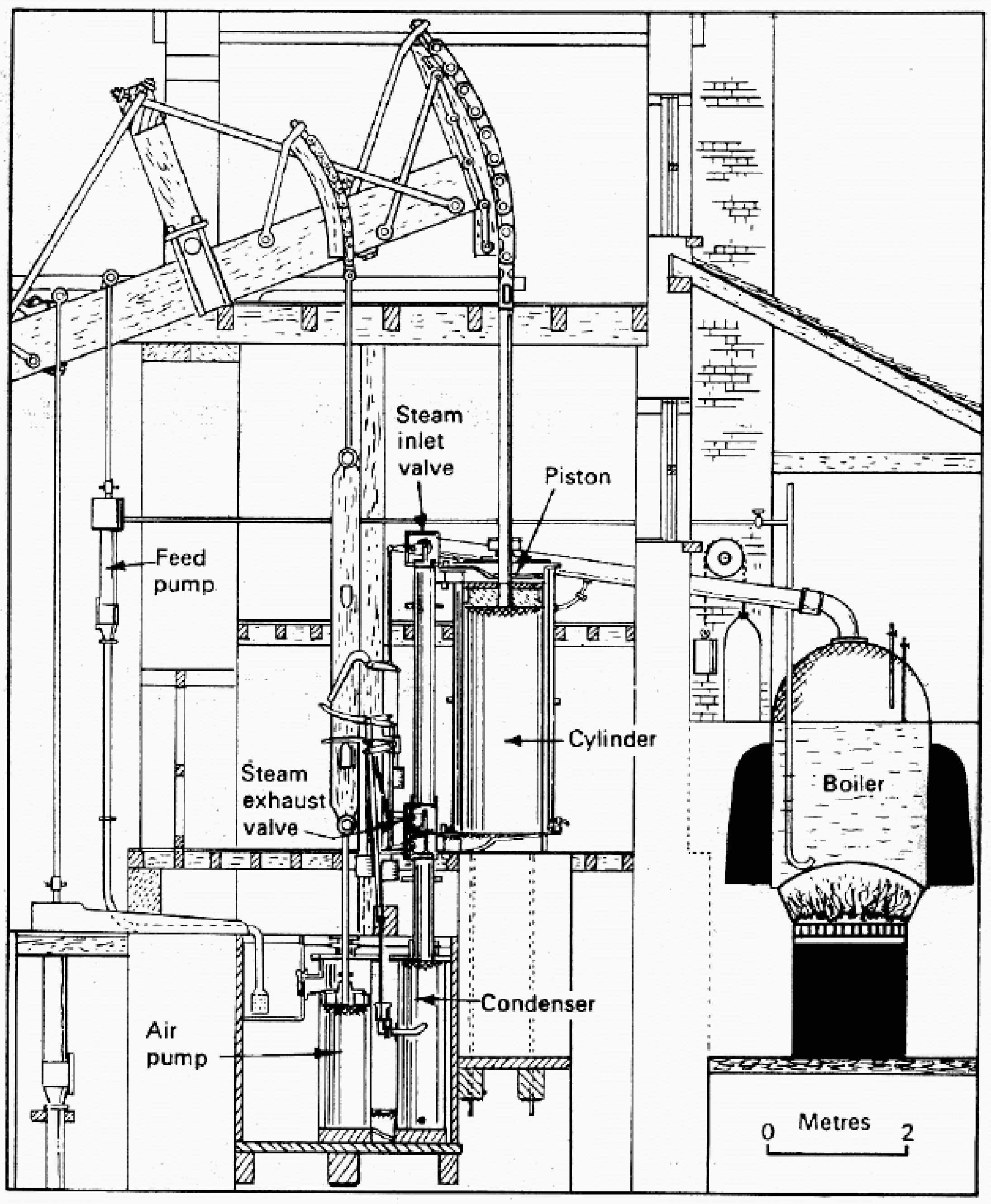
Watt

Vacuumpomp

Werkzuiger blijft op temp.

75 % minder brandstof dan Newcomben

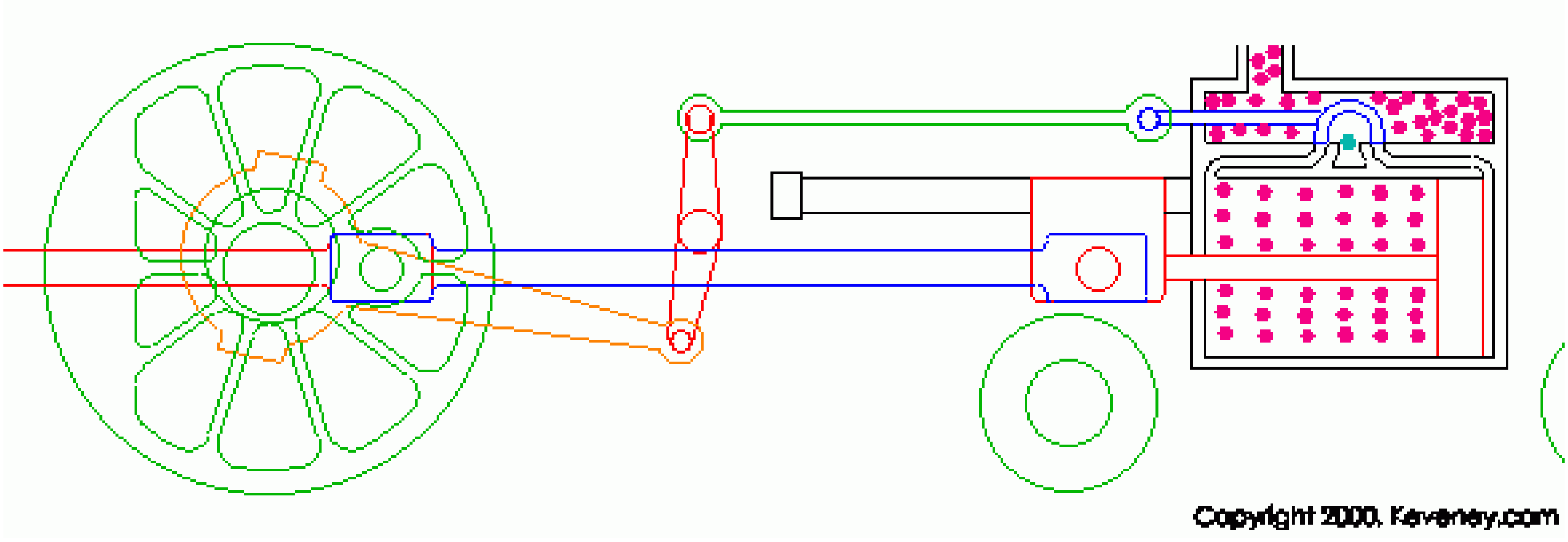
Verschil in kracht op / neer



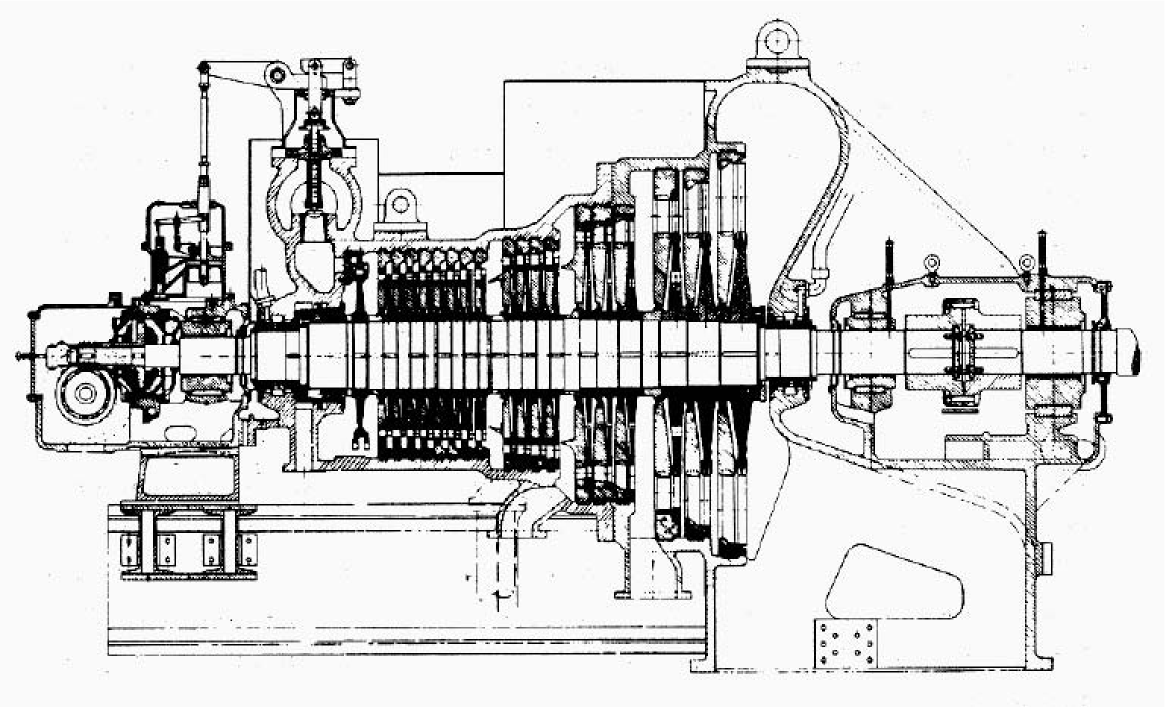
Watt's steam engine of 1788

locomotion steam engine, met bakschuif

beide slagen even krachtig



modern steam turbine



More than 80% of our electricity is generated via a steamturbine

concise history (II)

- Watt (1764): efficient steam engine
- till 1800: 'heat' is a weightless fluid: *flogiston*
  heat is released by cutting matter
- Rumford (1798): blunt drills generate more heat
- Davy (1810): friction produces heat
- Carnot (1824): heat yields more work when it flows from high to low temperature
  (2^{nd} Law of Thermodynamics)
- Around 1850:
  Mayer, Joule: relation between **heat** and **work**
  (1^{st} Law of Thermodynamics)

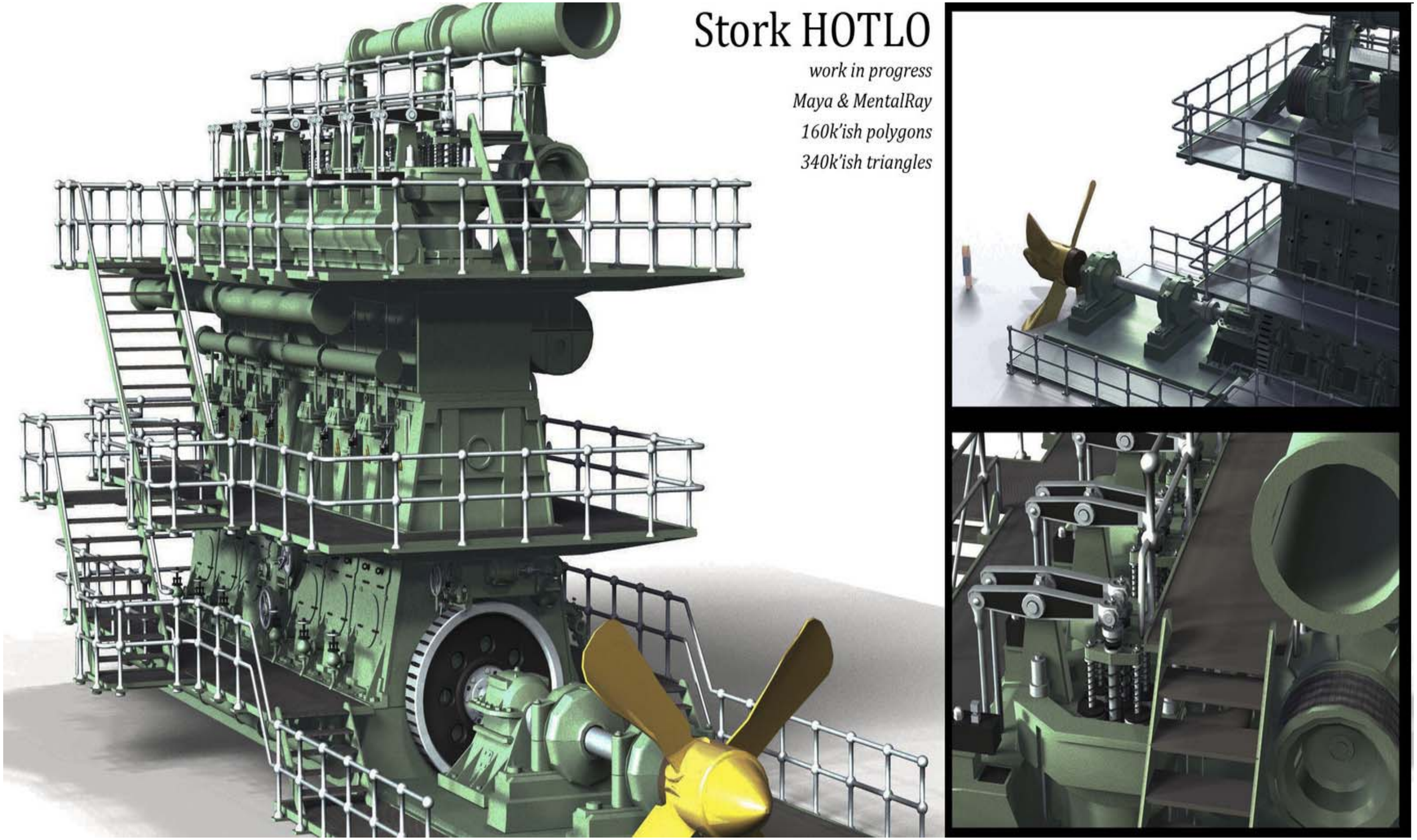
concise history (III)

- Clausius, Kelvin — systematic approach thermodynamics
- Fowler (1930) — 0^{th} Law of Thermodynamics

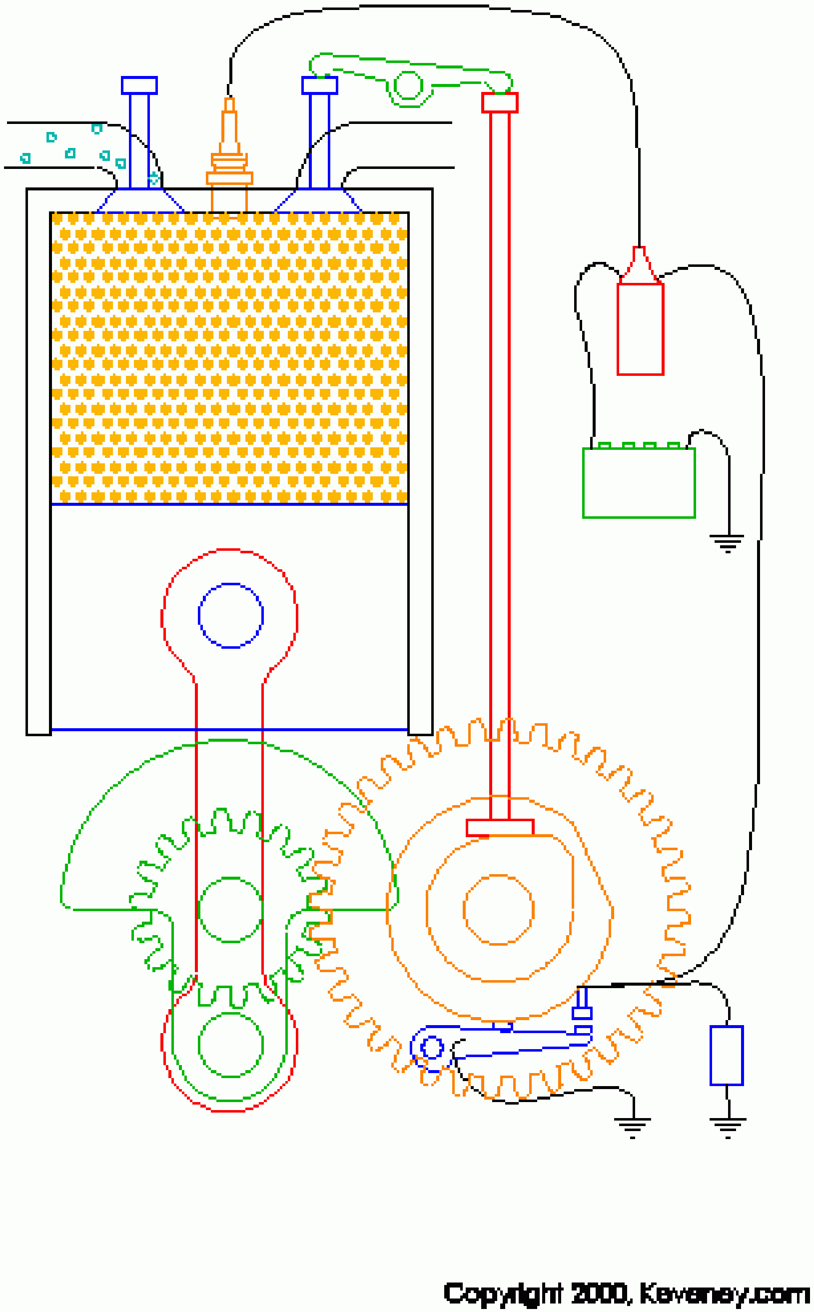
Classical Thermodynamics

- Dalton (~1800) — atom $\rightarrow$ statistical thermodynamics
- Planck (~1900) — quantum mechanics
- Einstein (1905)

Stork HOTLO


Stork HOTLO
work in progress
Maya & MentalRay
160k'ish polygons
340k'ish triangles

V8 engine



TUDelft

- **classical thermodynamics**
  - *equilibrium* $\rightarrow$ ‘time does not matter’
  - empirical: based on observation and experiment

- **most practical problems:**
  no equilibrium and *transients*
  heat flows, liquids and gases flow; in practice we also need heat and mass transfer and fluid mechanics

- **Fundamentals laid down in four principle laws:**
  - 0^{th} Law: equilibrium and existence of temperature
  - 1^{st} Law: conservation of energy
  - 2^{nd} Law: limitations nature implies on processes
  - 3^{rd} Law: reaching zero absolute temperature

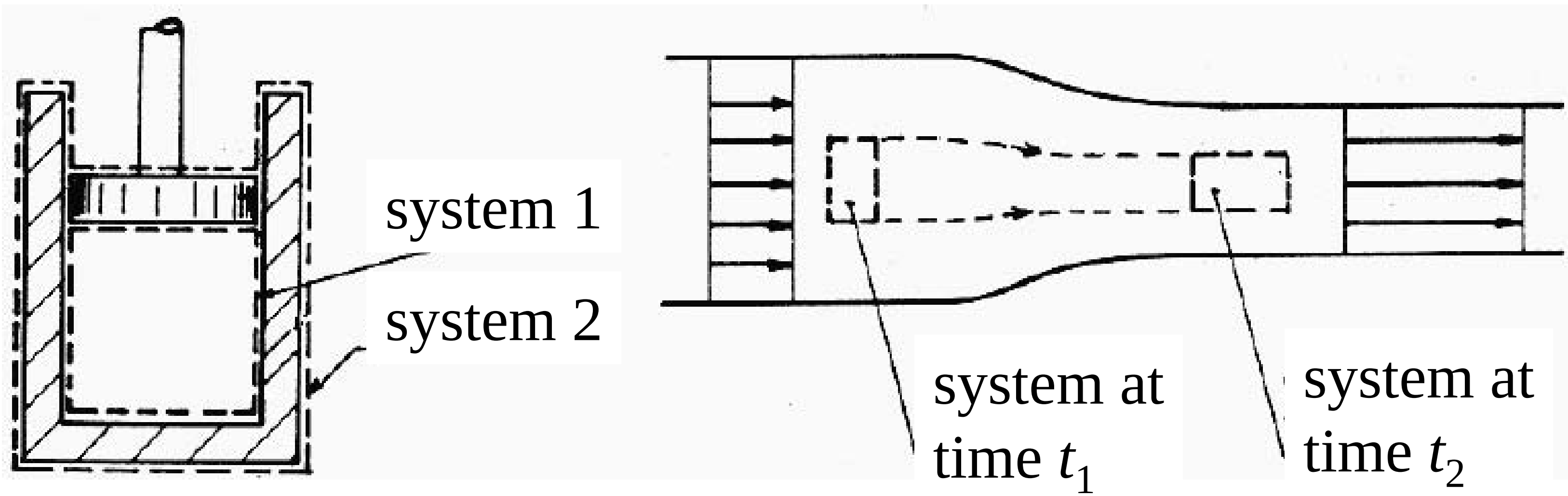
concepts / definitions

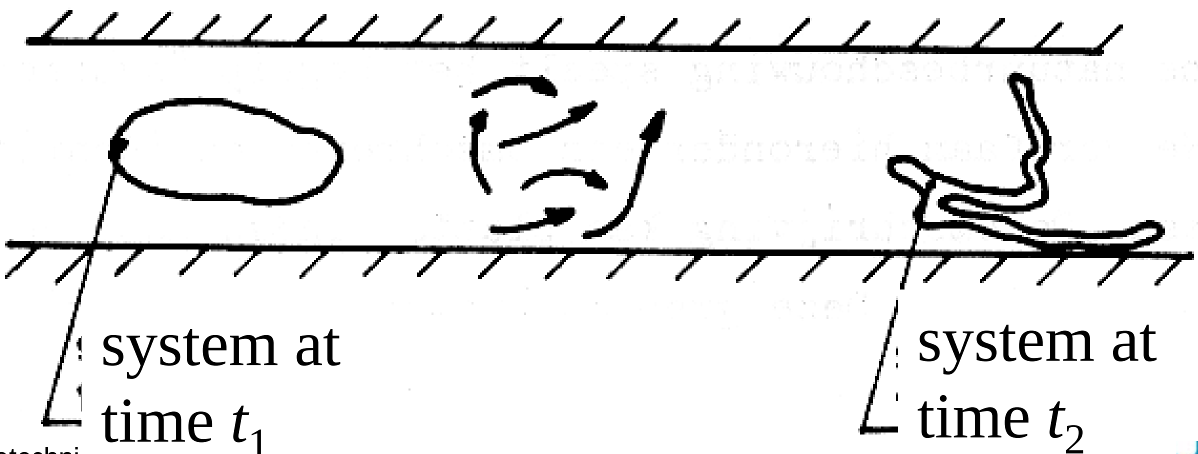
- system
- continuum
- thermodynamic equilibrium
- property and state
- process

system

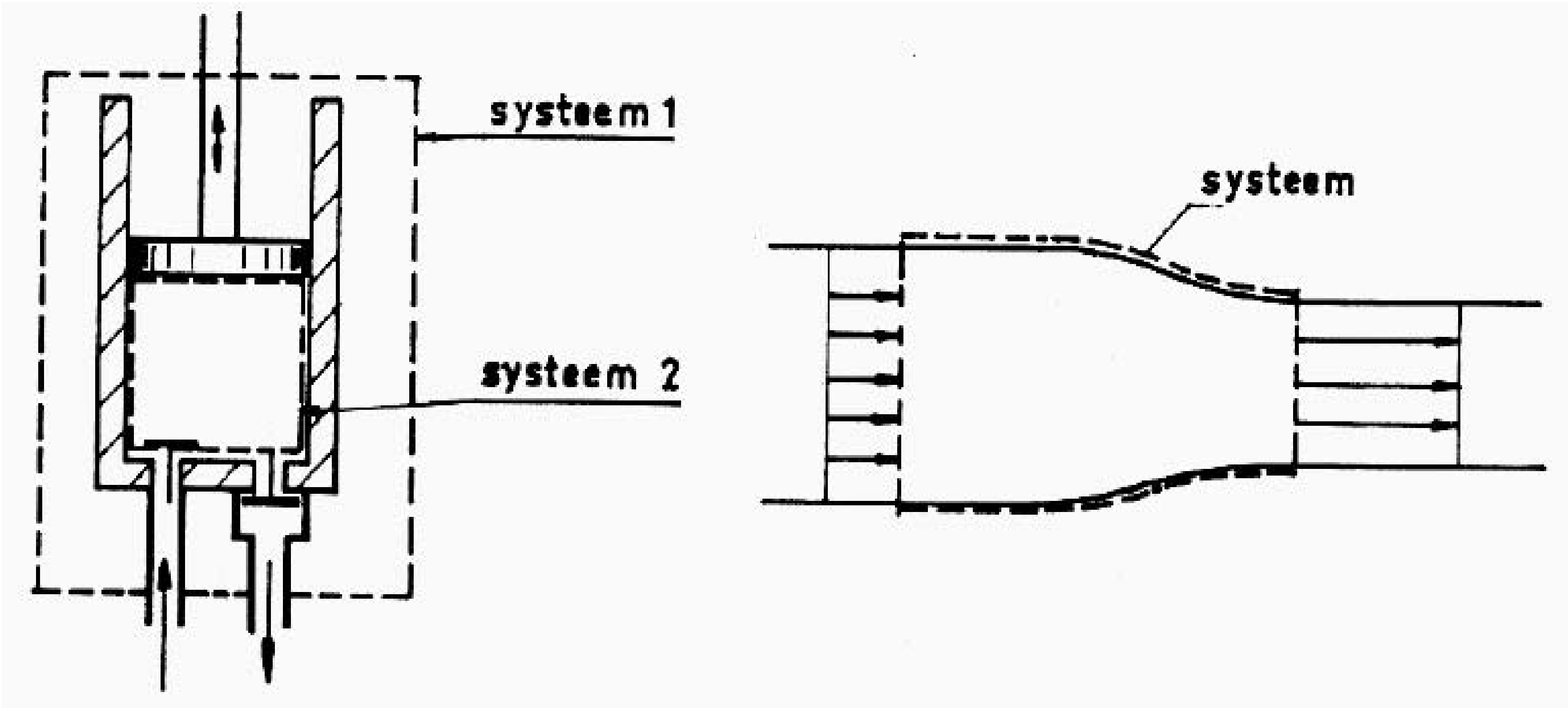
- **system** = the matter that is considered
- defined by its **boundary**
- **surroundings**: everything external to the system
- exchange system/surroundings through the boundary: matter and energy (as heat and work)
- First, we make a distinction between **open** and **closed** systems based upon the inflow and outflow of *matter:*
  - **closed** system: no matter passes through the boundary
  - **open** system: matter passes through the boundary

examples of closed systems





examples of open systems

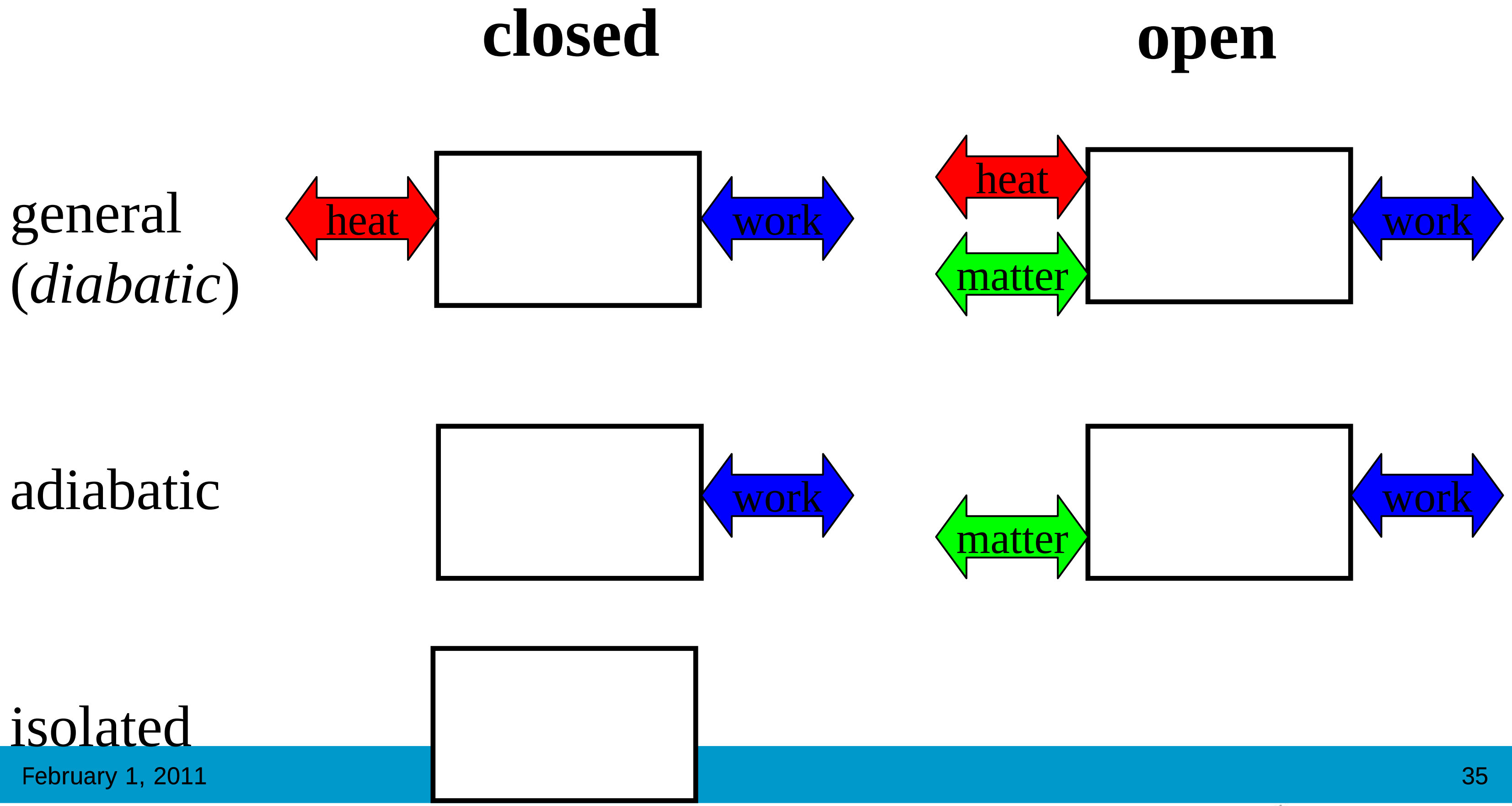


open system ⇒ ‘control volume’

system (cont'd)

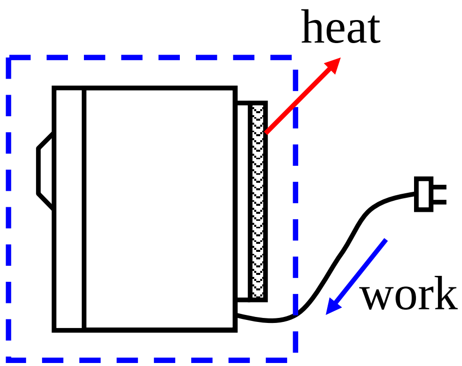
- except matter, also *energy* can be exchanged with the surroundings in the form of *heat* and *work*:
  - **general (*diabatic*) system:**
    a *diabatic* system can exchange both heat and work with its surroundings
  - **adiabatic system:**
    an adiabatic system does **not** exchange energy in the form of **heat**
- furthermore:
  - **isolated** system:
    an isolated system has **no** exchange with surroundings

systems: summary

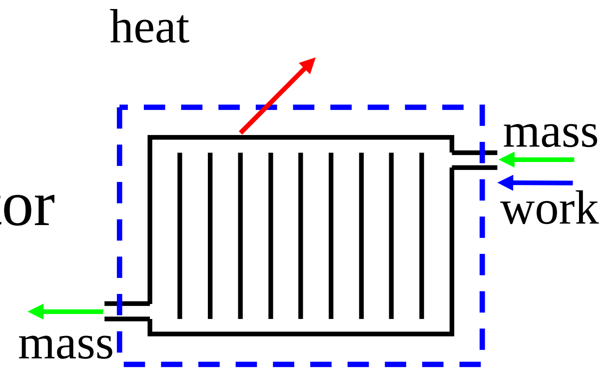


systems: examples

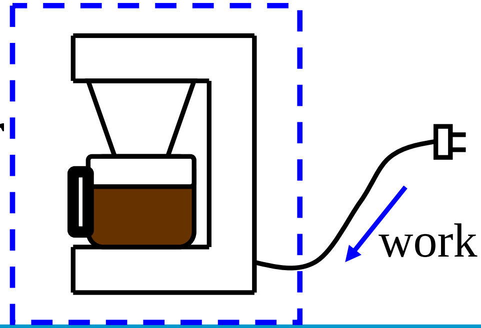
closed:
refrigerator



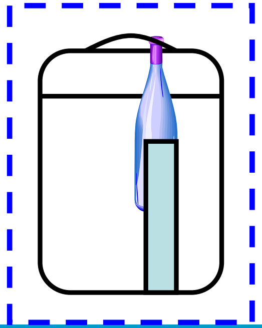
open:
radiator



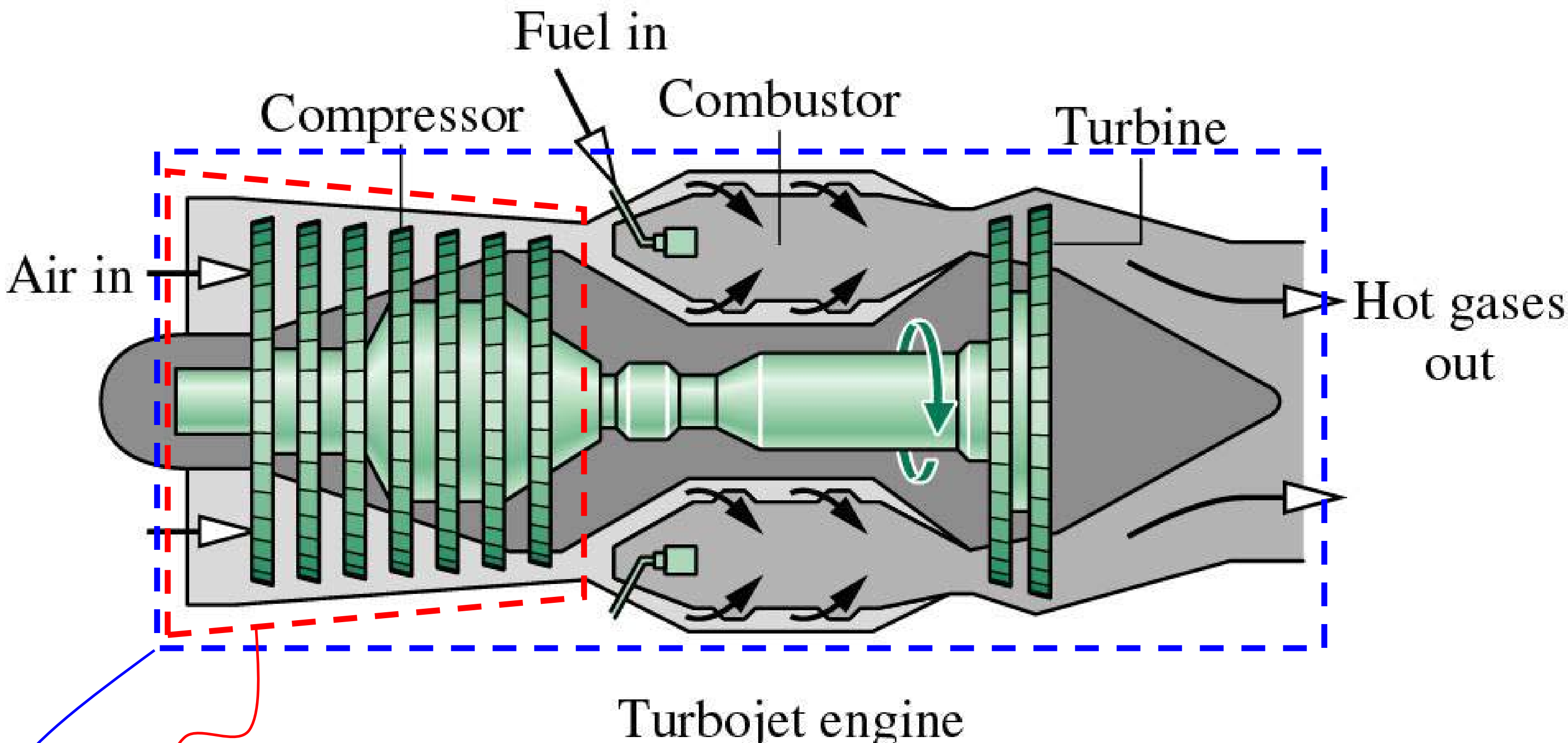
adiabatic:
coffee maker



isolated:
cooler with
hot bottle and
freezer pack



System boundaries



system boundary for (detailed) analysis or design of compressor

system boundary for analysis of overall jet engine

⇒ you can decide on the system boundary that is appropriate for your task

continuum

In thermodynamics matter is considered to be a *continuum*.
Example: density

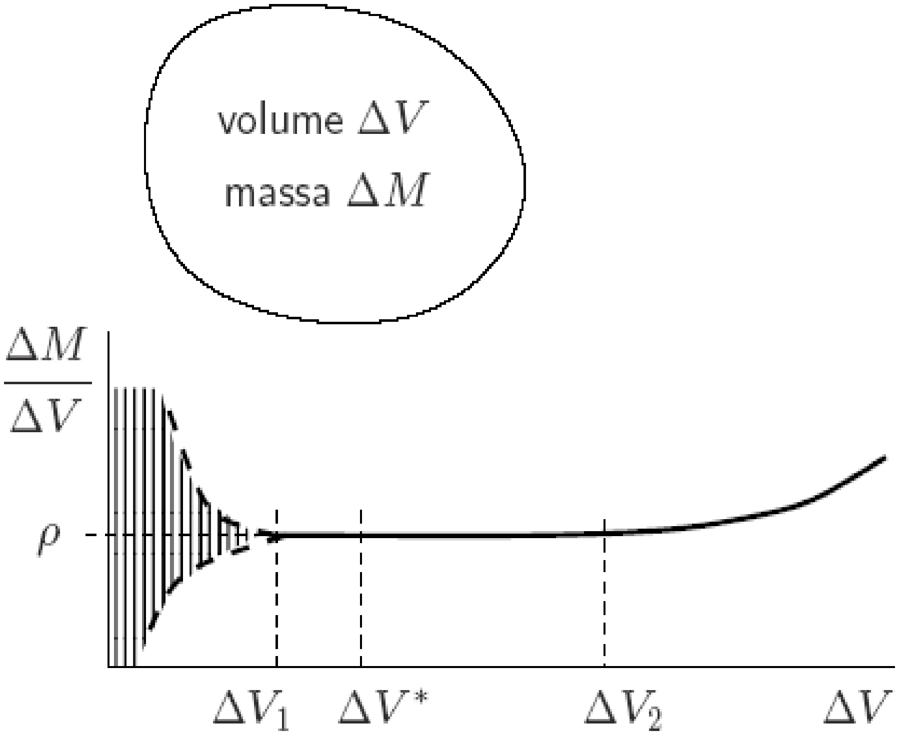
$$\rho = \frac{\Delta M}{\Delta V}$$

taking the zero volume limit:

$$\lim_{\Delta V \to 0} \frac{\Delta M}{\Delta V} = ?$$

local 'point' density:

$$\rho = \lim_{\Delta V \to \Delta V^*} \frac{\Delta M}{\Delta V}$$



The density thus defined is a *macroscopic* property

thermodynamic equilibrium

Important observation:

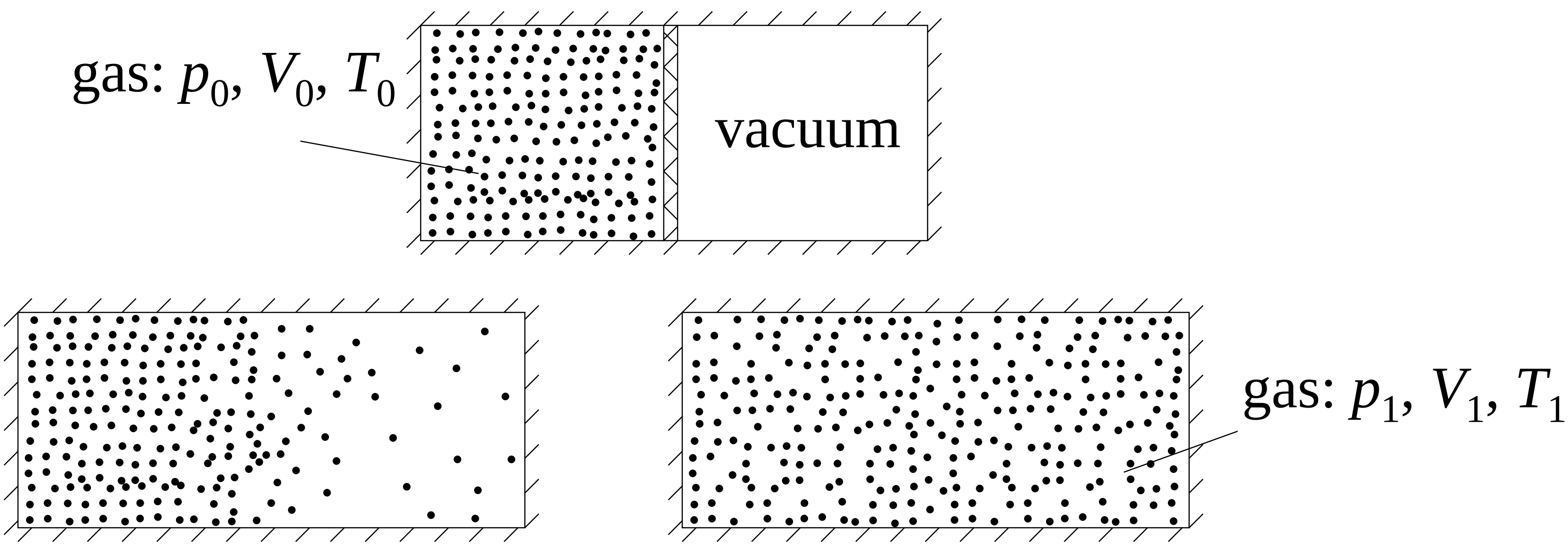
an isolated system eventually reaches
a time independent state

This final state we call a (thermodynamic) *equilibrium state.*

So: equilibrium state = isolated system (or can be isolated without changing its state)

Examples:

- Creamer and sugar added to a cup of coffee (after stirring) will eventually become a quiescent homogeneous mixture that does not change
- After closing the cap of a soda bottle an equilibrium between the CO_2 in the air and water will be established



after a short time

after a much longer time

Classical thermodynamics only considers equilibrium states but not how these states are reached → 'thermostatics'

variables of state *or* properties

The state of a system is specified by (a small number of) variables: *state variables* or *properties* (book).

A property is independent of the way the state is reached! The magnitude of a change in a property only depends on the initial state and final state, and not on the path.

Example: the state of an ideal gas in an equilibrium is determined by its temperature T and volume V.
The work done by the gas is not a property.

More properties exist than we need to uniquely specify a state. We then select the most appropriate ones (e.g., T and V); the other are given by the *equation of state*, e.g. $p = f(V,T)$.

(Classical) thermodynamics considers equilibrium states only.

intensive: an intensive property does not change when the system is changed in size (e.g., temperature and pressure)

extensive: an extensive property changes proportionally to the size of the system (e.g., mass, volume and energy)

specific: a specific state is an extensive property per unit mass (or per kmol):

Example: specific volume: $v = \dfrac{V}{m} = \dfrac{1}{\rho}$

(book: the specific volume in kmol is denoted by: $\bar{v}$)

specific properties are intensive properties.

process

A **process** is defined as the change of the state of a system.

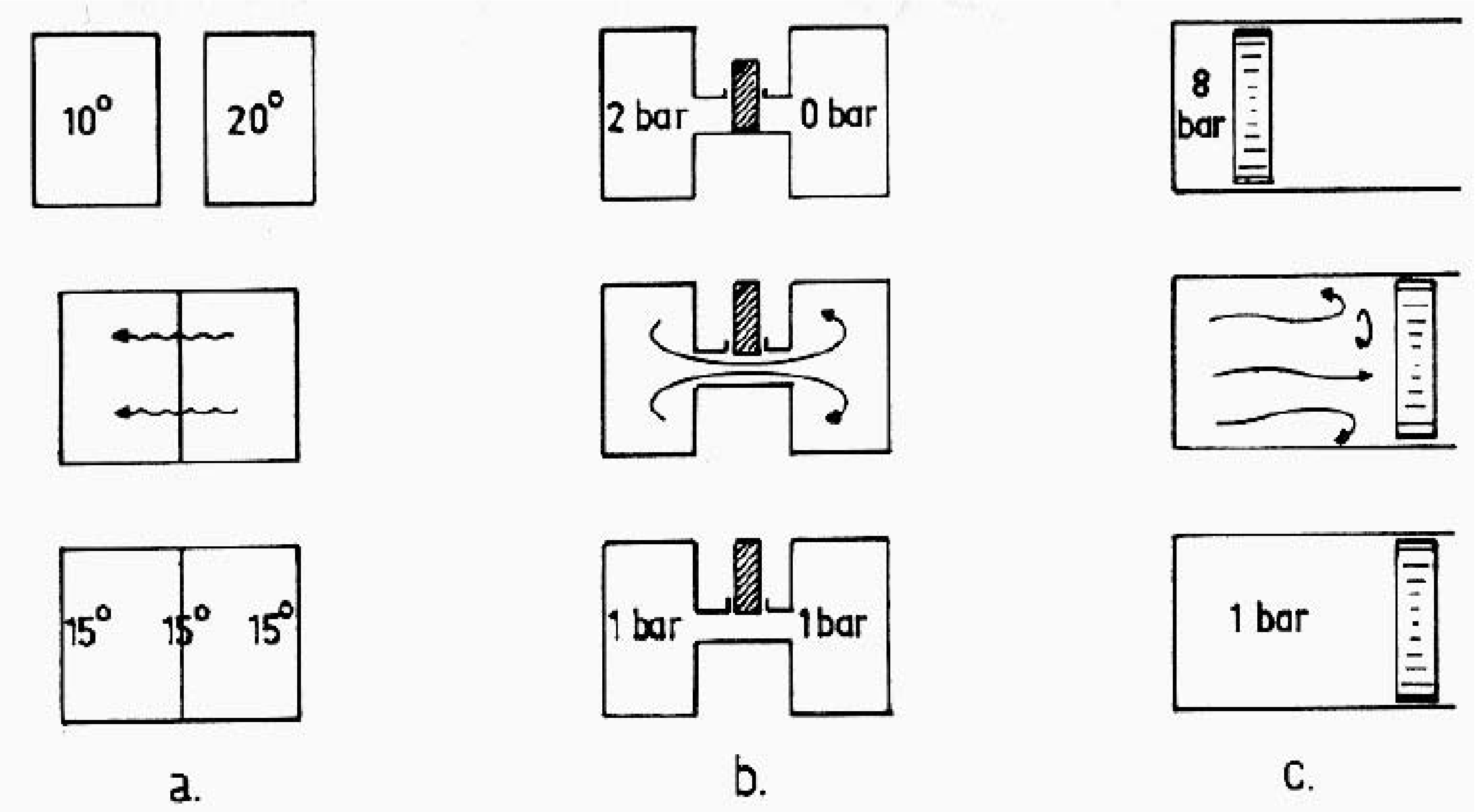
We only consider changes from one equilibrium state to another

The state of a system has changed when the properties (in an equilibrium state) have changed. During the change the system is not in equilibrium.

A (thermodynamic) **cycle** is a process where the initial and final states are identical.

adiabatic system $\rightarrow$ adiabatic process
isolated system $\rightarrow$ isolated process

process: examples



the quasi-static process

quasi-static process:
divide the process into infinitesimal state changes and let the system relax to an equilibrium state at every change

Example: slowly move a piston in a cylinder

Because the process consists of a series of equilibrium states the equilibrium equations of state remain valid.

The process can also be done in the reverse direction, so a quasi-static process is **reversible**.

We assume that all processes considered in this lecture series are quasi-static (unless stated otherwise)

Instructions

- Chapter 1 to 1.6 has been treated – read this thoroughly in book !!!
- Self-study: 1.4.1 (SI units) and 1.5.2 (pressure)
- Solve the exercises 1.1-1.4, & 1.6-1.8, & 1.10-1.13, 1.21 & 1.22