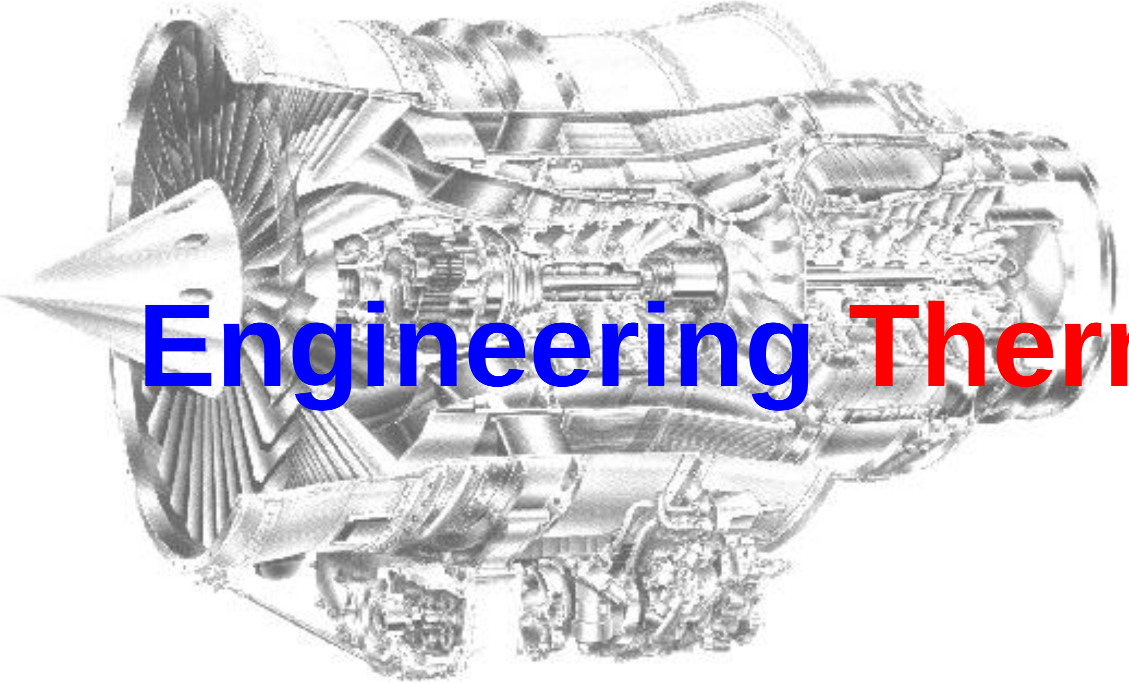
Engineering Thermodynamics

Basic Concepts - 1



Schedule

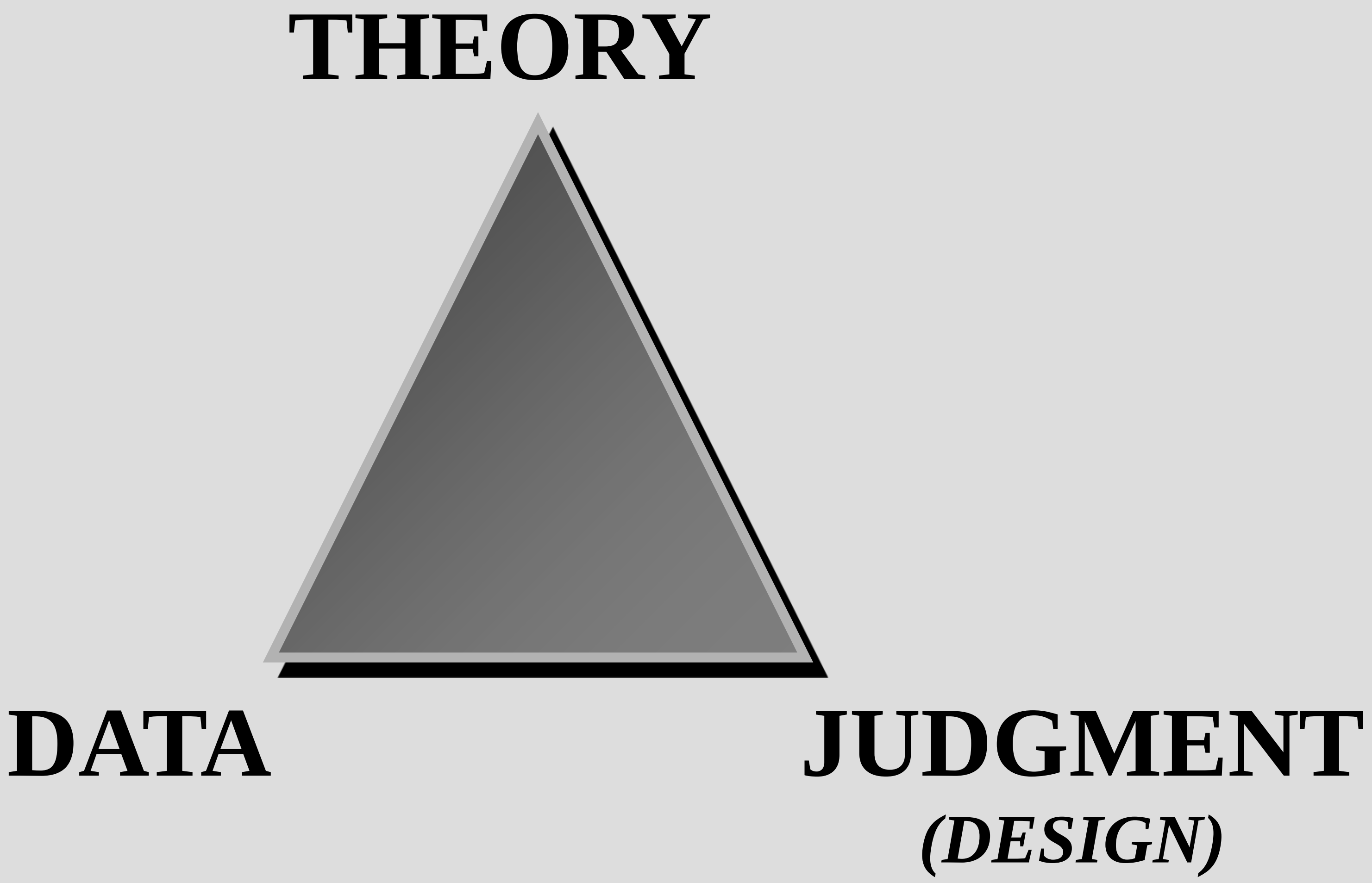
Lectures	Subjects
1	Schedule & Introduction
2	Basic concepts - 1
3	Basic concepts - 2
4	Basic concepts - 3
5	Basic concepts - 4
6	Basic concepts - 5
7	1st law of thermodynamics - 1
8	1st law of thermodynamics - 2
9	1st law of thermodynamics - 3
10	1st law of thermodynamics - 4
11	1st law of thermodynamics - 5
12	1st law of thermodynamics - 6
	Midterm exam

Lectures	Subjects
13	2nd law of thermodynamics - 1
14	2nd law of thermodynamics - 2
15	2nd law of thermodynamics - 3
16	2nd law of thermodynamics - 4
17	2nd law of thermodynamics - 5
18	2nd law of thermodynamics - 6
19	2nd law of thermodynamics - 7
20	2nd law of thermodynamics - 8
21	Cycles - 1
22	Cycles - 2
23	Cycles - 3
24	Cycles - 4
	Final exam

Outline

- General overview
- What is thermodynamics?
- History of thermodynamics
- Why do we study thermodynamics?
- General thermodynamic systems
- Closed vs. open systems
- Macroscopic vs. microscopic viewpoints

The engineering framework



General overview

- Mechanical Engineering
  - Mechanics
  - Energy
  - Systems
  - Design

The over arching goal is design of products to meet societal needs.

- Thermodynamics
  - A part of the Energy component of mechanical engineering.
  - Governs *all* energy consuming and transforming devices and system.

Thermodynamics and Energy

Thermodynamics **is defined as the science of Energy and includes all aspects of energy transformations, including power production, refrigeration, and relationship among the properties of matter.**

The *first law of thermodynamics* is simply an expression of the conservation of energy principle, and it asserts that *energy* is a thermodynamic property.

The *second law of thermodynamics* asserts that energy has *quality* as well as *quantity*, and actual processes occur in the direction of decreasing quality of energy → "entropy".

History of Thermodynamics

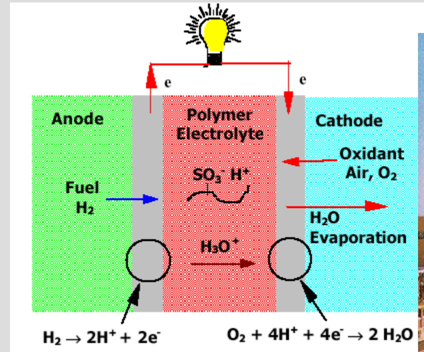
- Greeks: "the power of heat"
- To understand steam engines in the 18th century

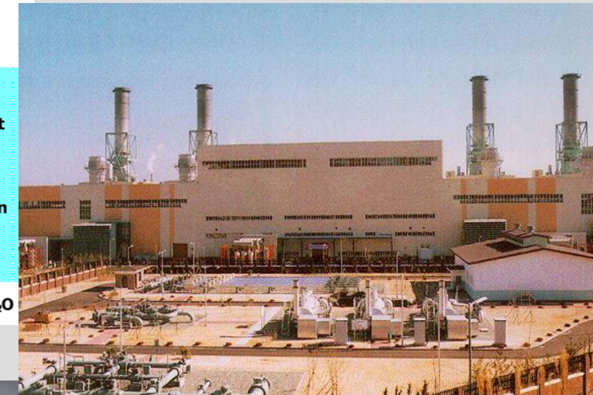
Richard Trevithick (1771-1833):
British inventor and mining engineer
Developed the first high-pressure steam engine in 1802

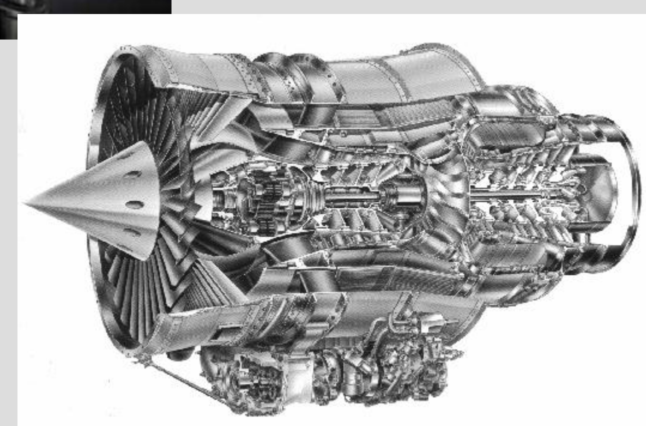
George Stephenson (1781-1848):
English civil engineer and mechanical engineer
Designed his first locomotive in 1814 (Blücher)
Built the first public inter-city railway line in the world to use steam locomotives

Motivations

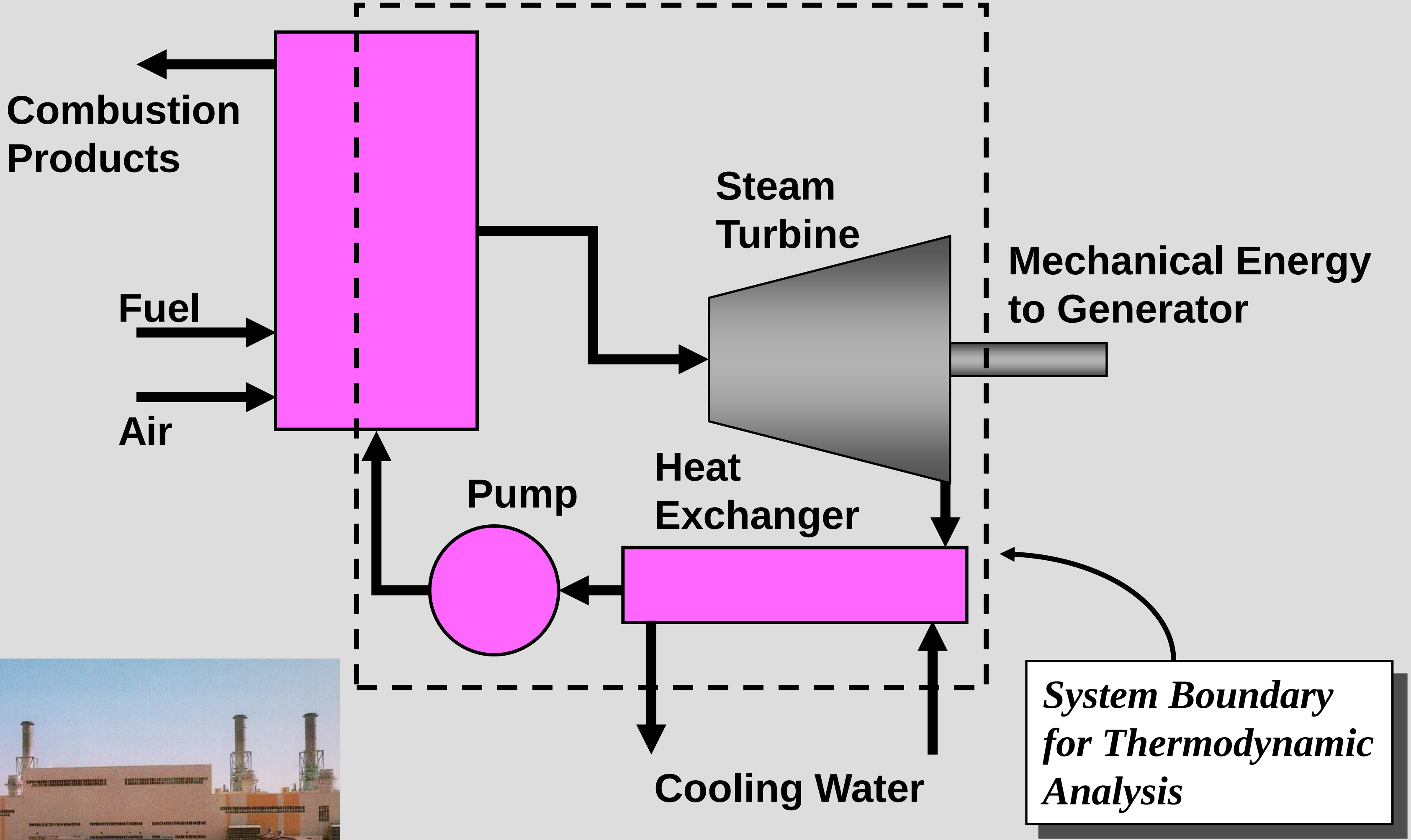
- Power plants
- Automotive engines
- Aircraft engines
- HVAC and IAQ
- Advanced TD systems
  - Power MEMS
  - Fuel cells



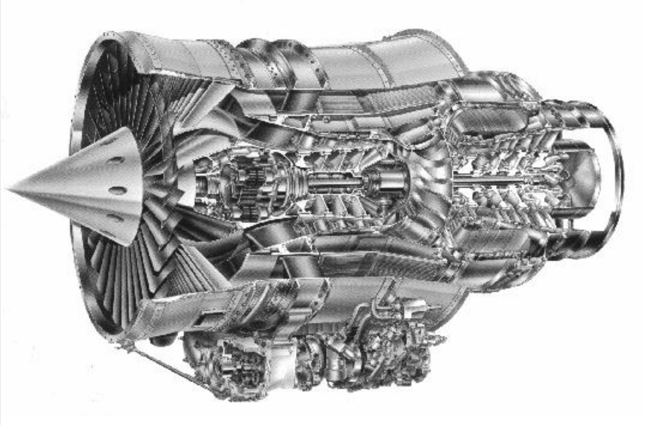


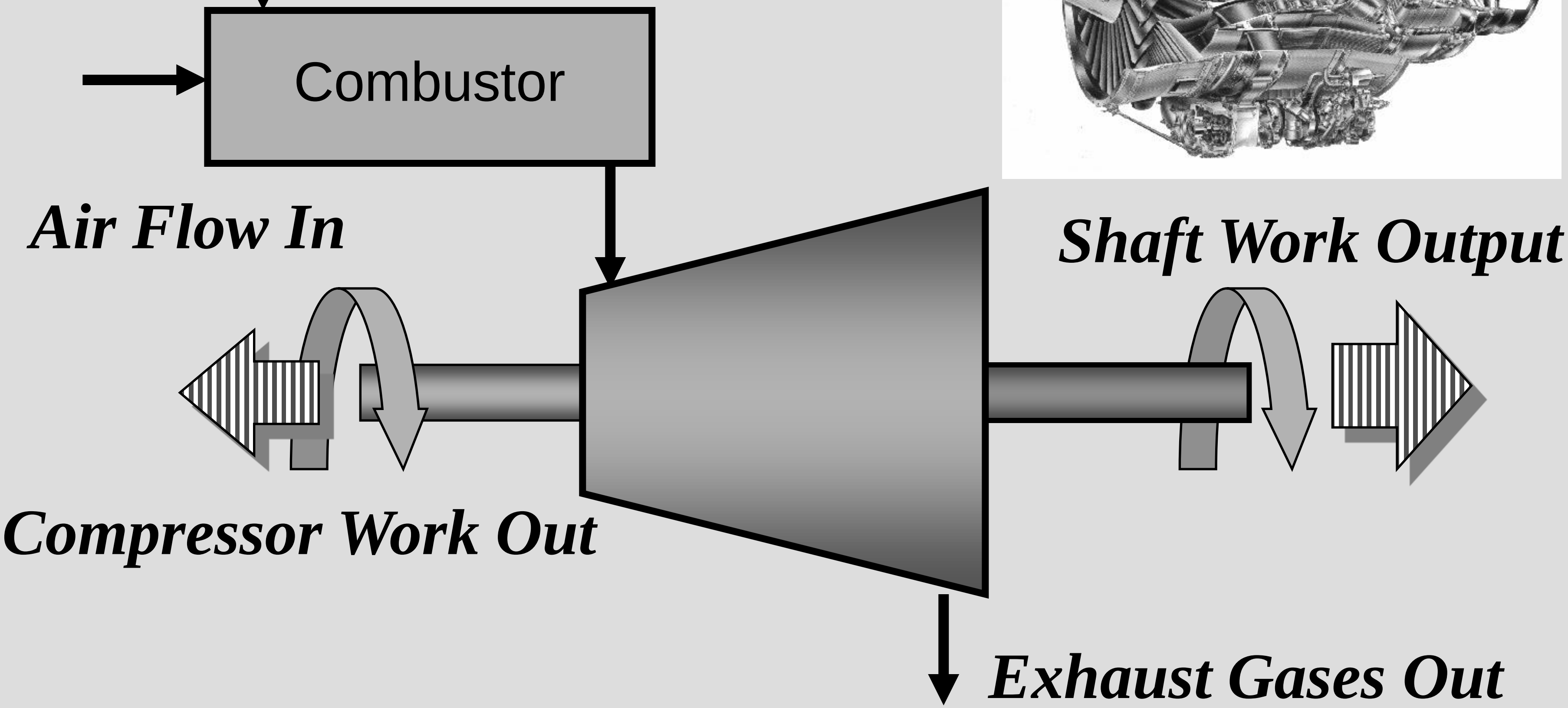


Example: A steam power plant



Example: A gas turbine engine

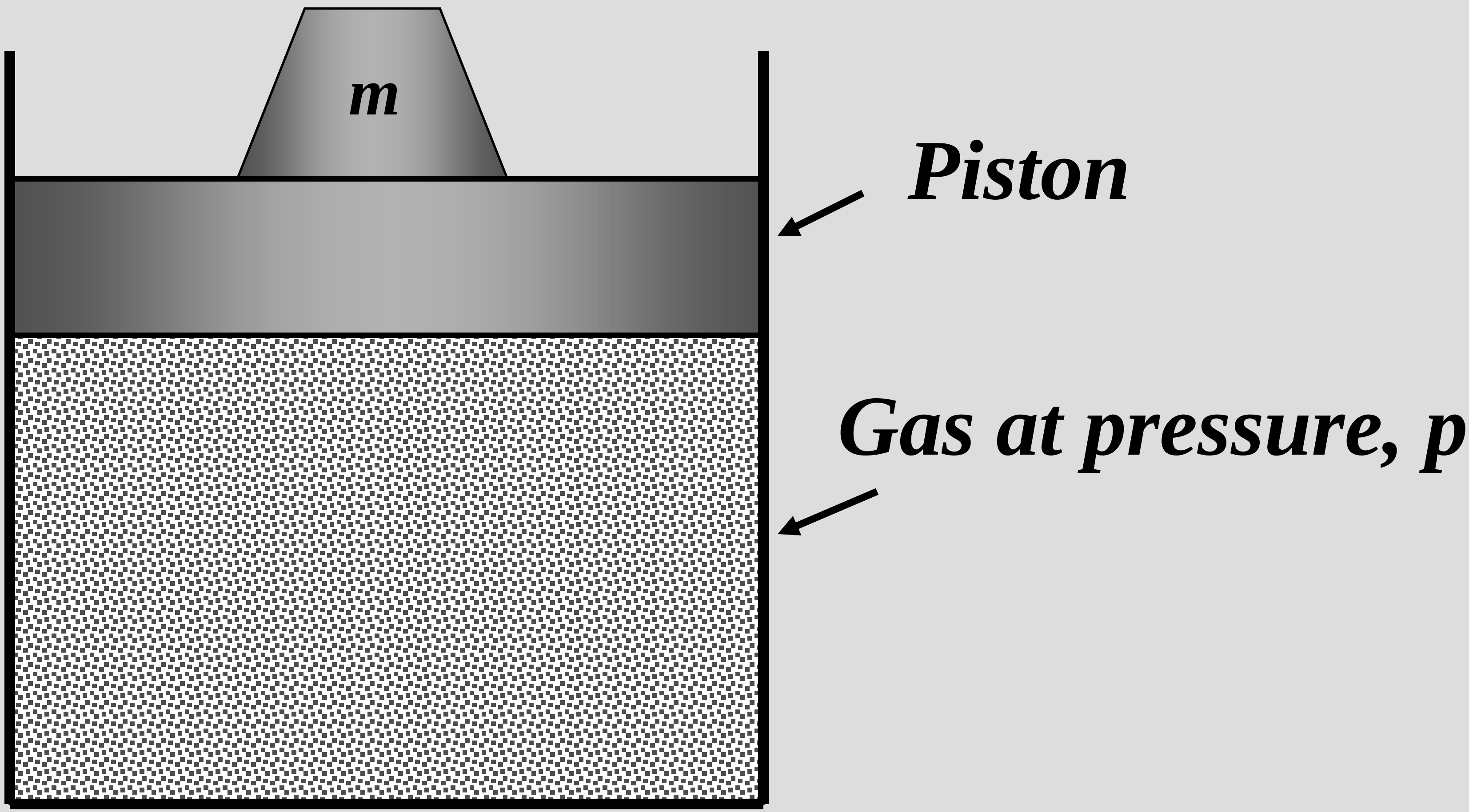




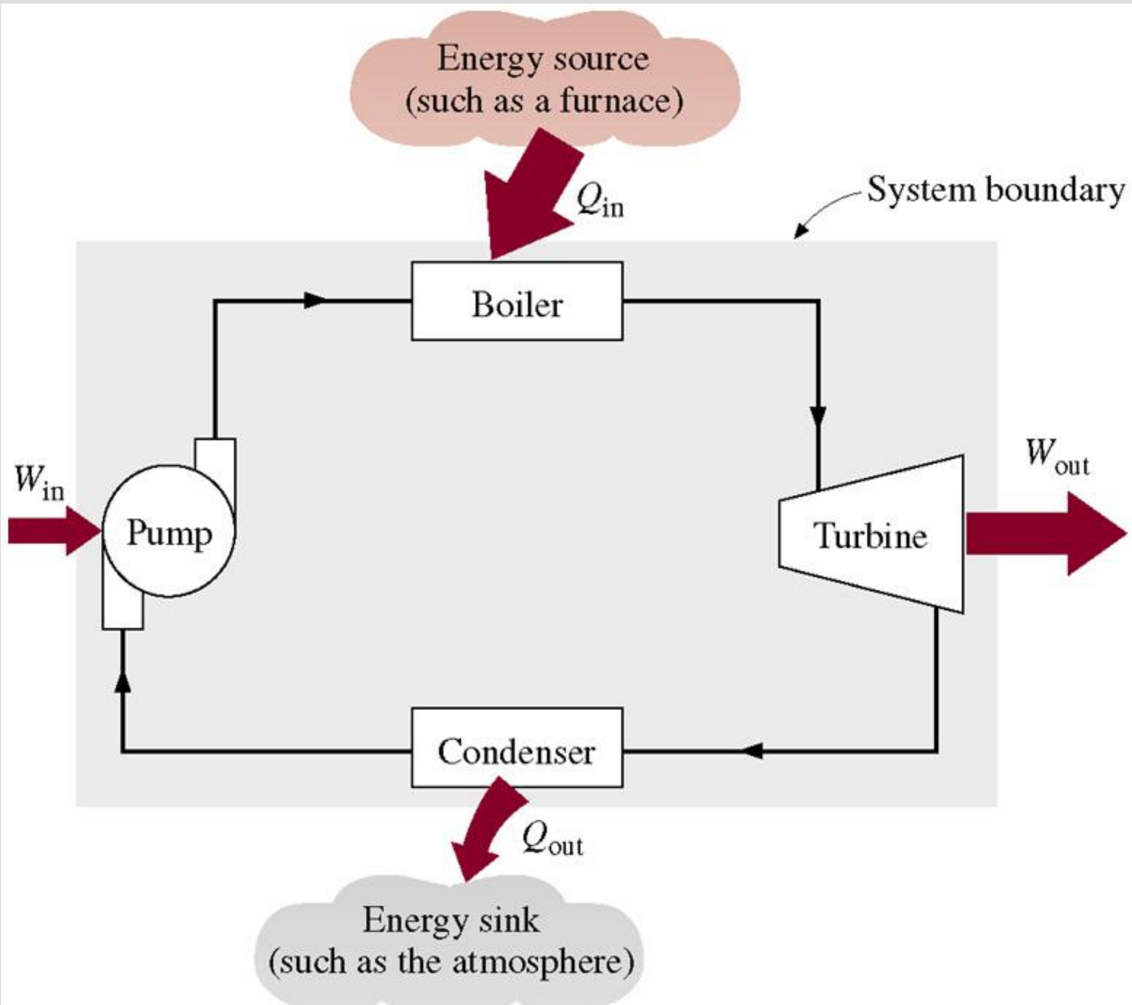
Example: An automotive engine

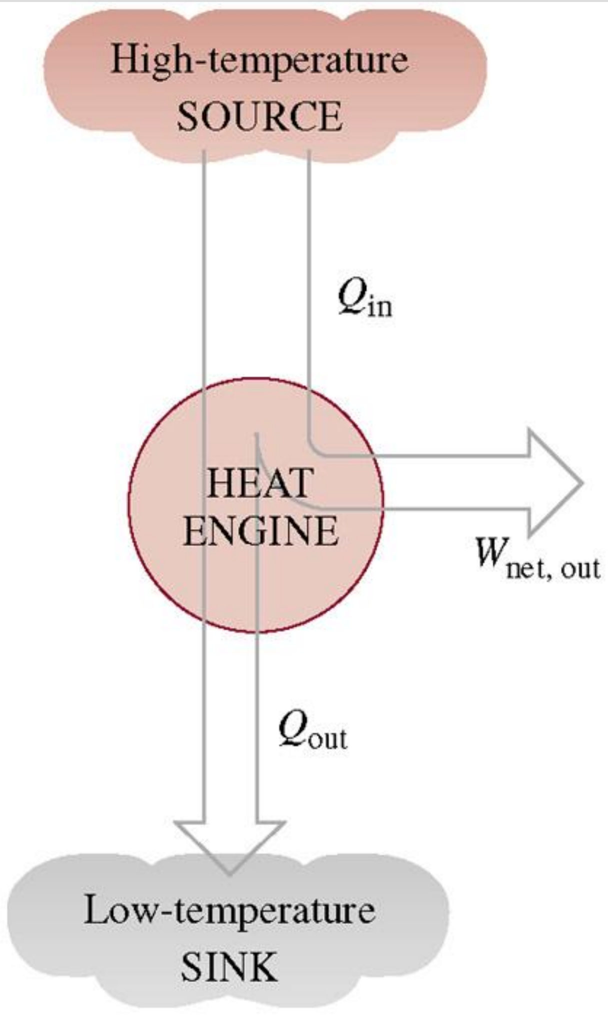
Engine.swf

Example: Piston and cylinder

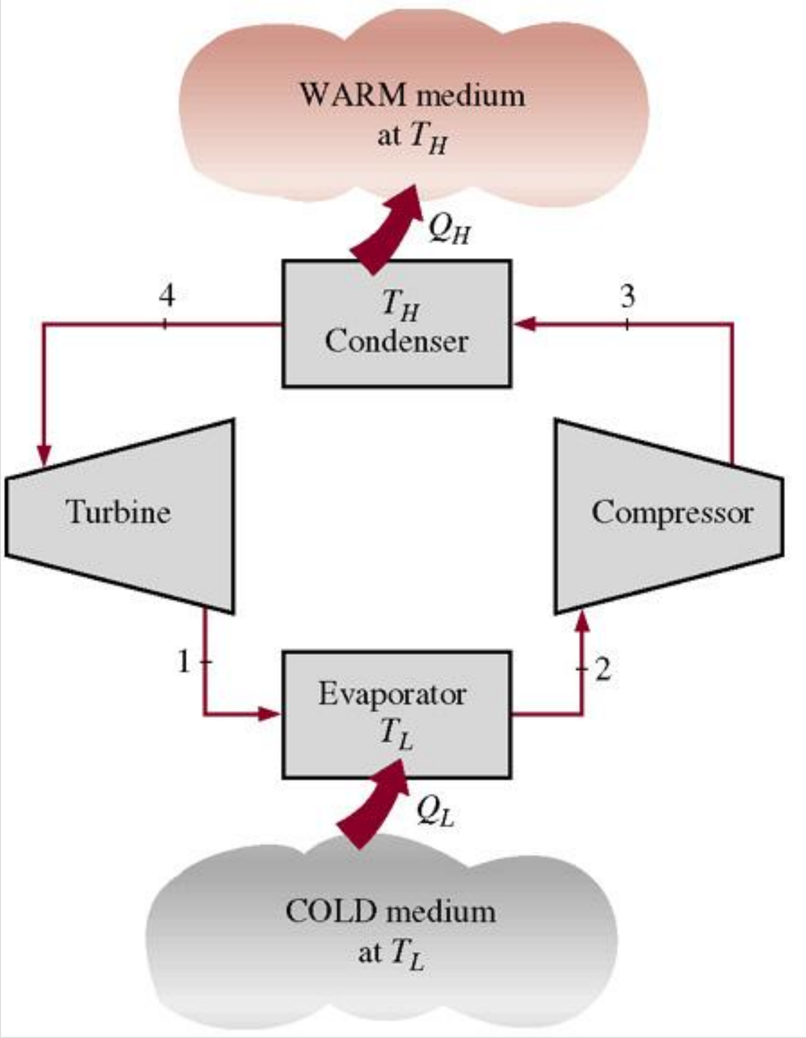


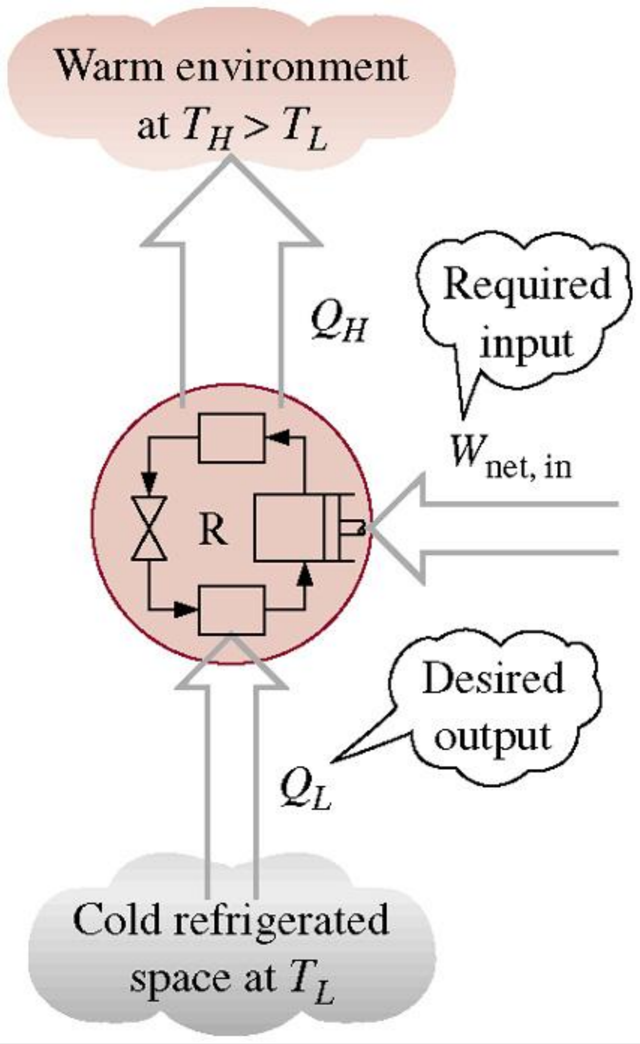
General thermal systems (heat engines)





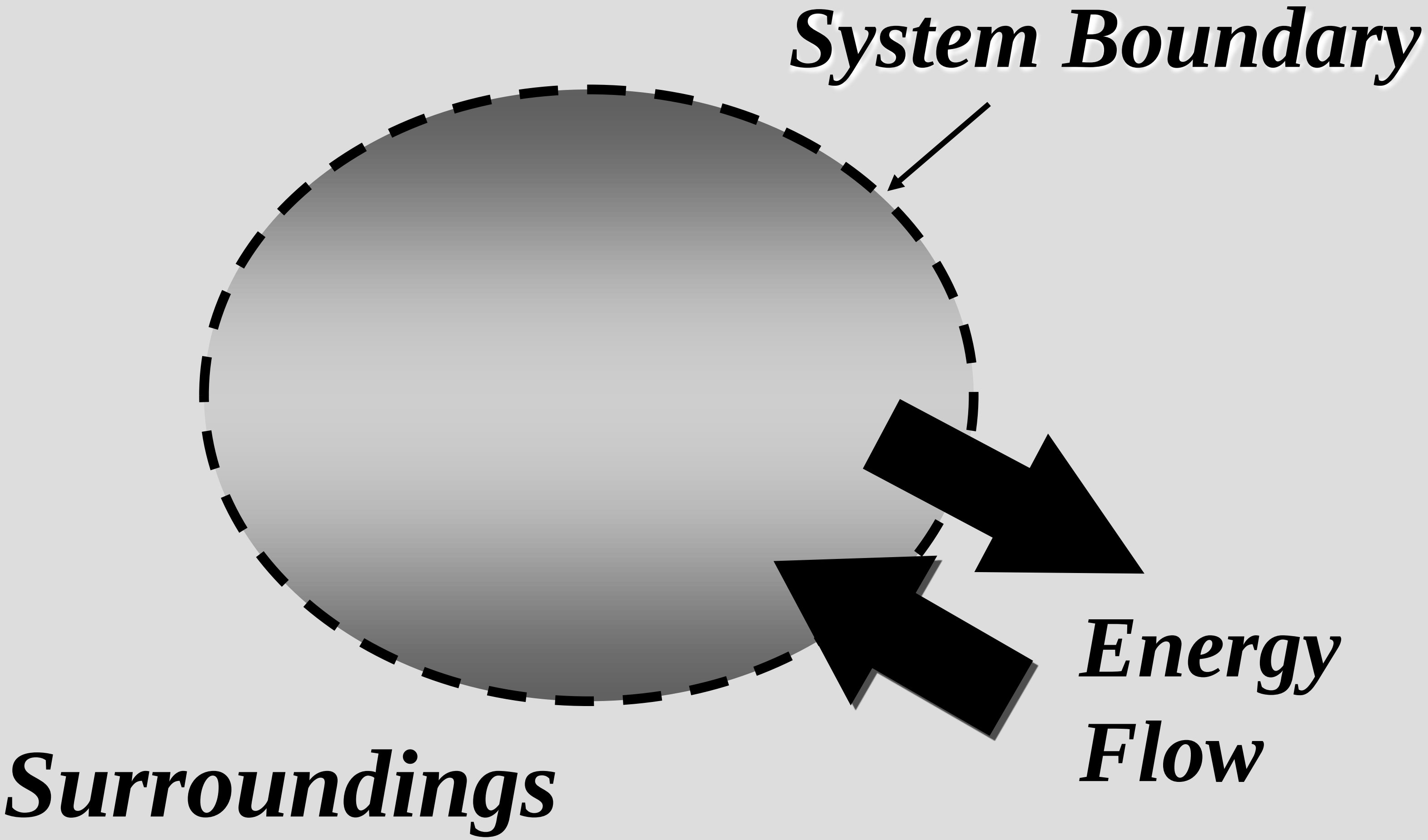
General thermal systems (refrigerator and heat pump)





How does the state of system change?

Energetic interactions



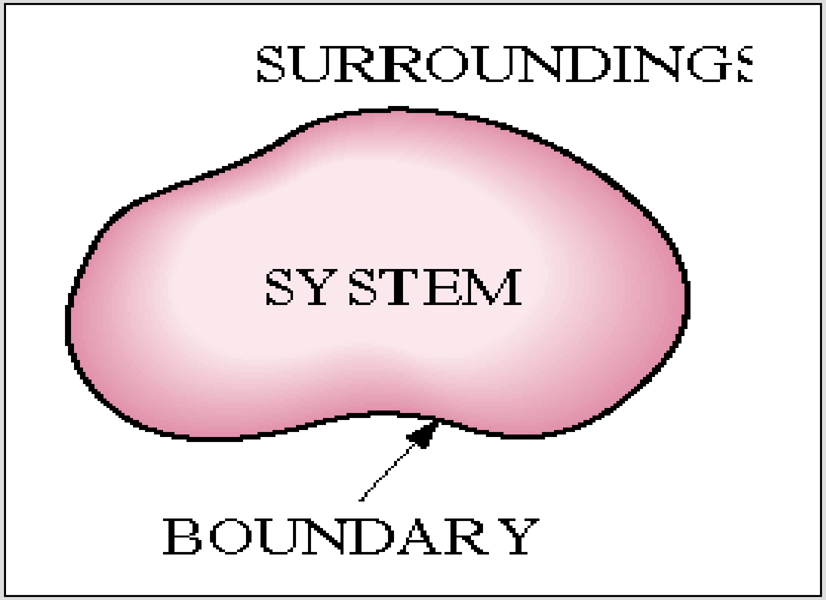
Basic definitions...

System, Surroundings and Boundary

A ***Thermodynamic System****,* or simply ***System*** is defined as a quantity of matter or a region in space chosen for study.

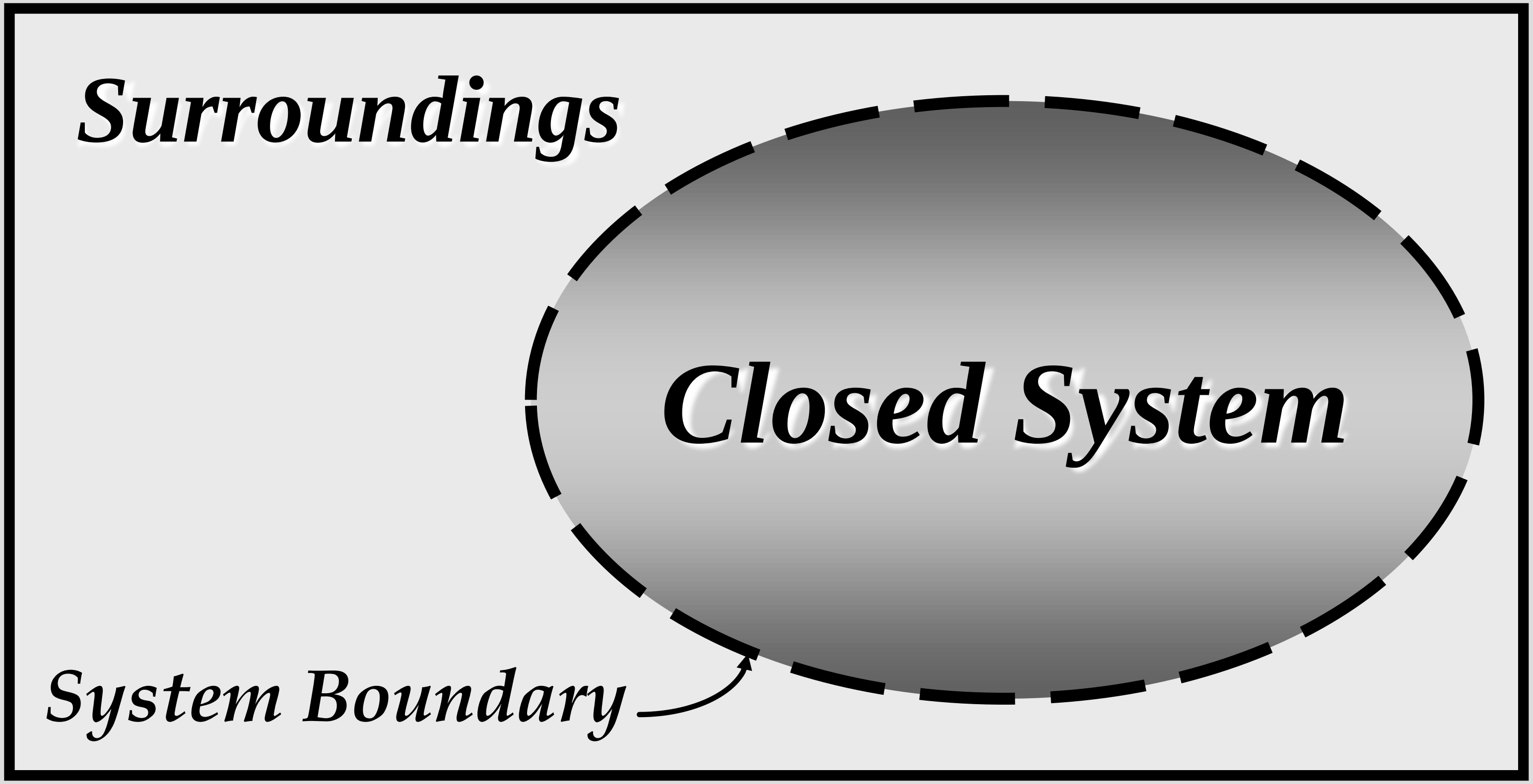
Surroundings is the mass or region outside the system.

Boundary is the real or imaginary surface that separates the system from its surroundings.



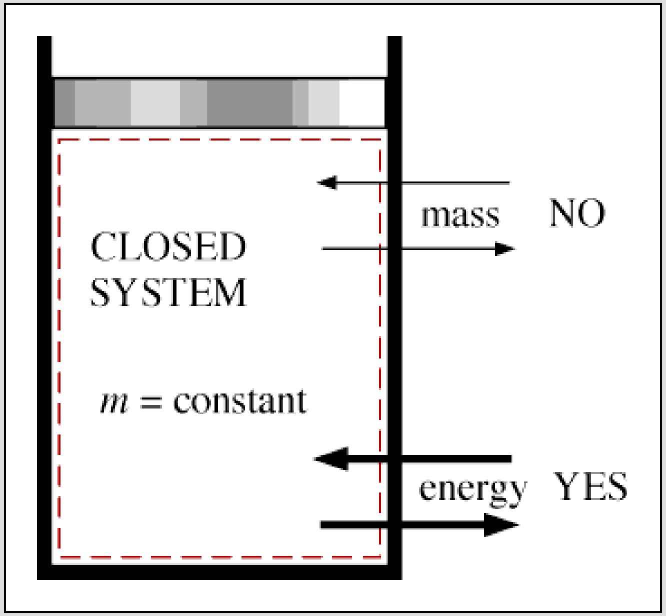
System and surroundings

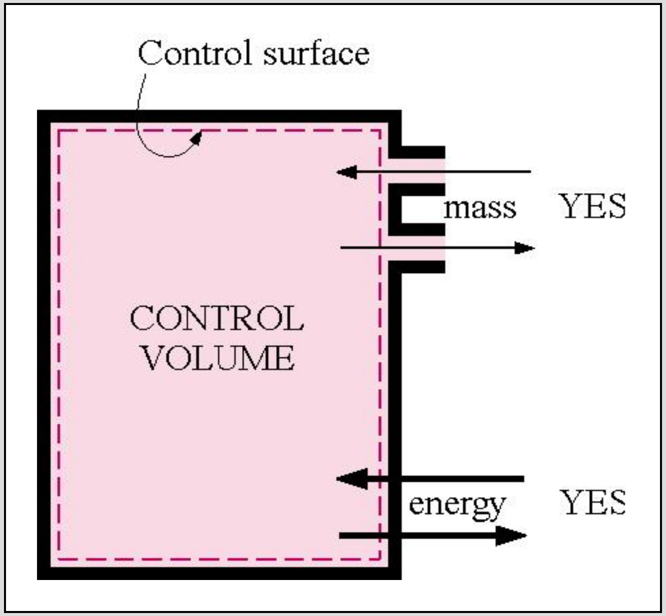
Universe = Systems +Surroundings



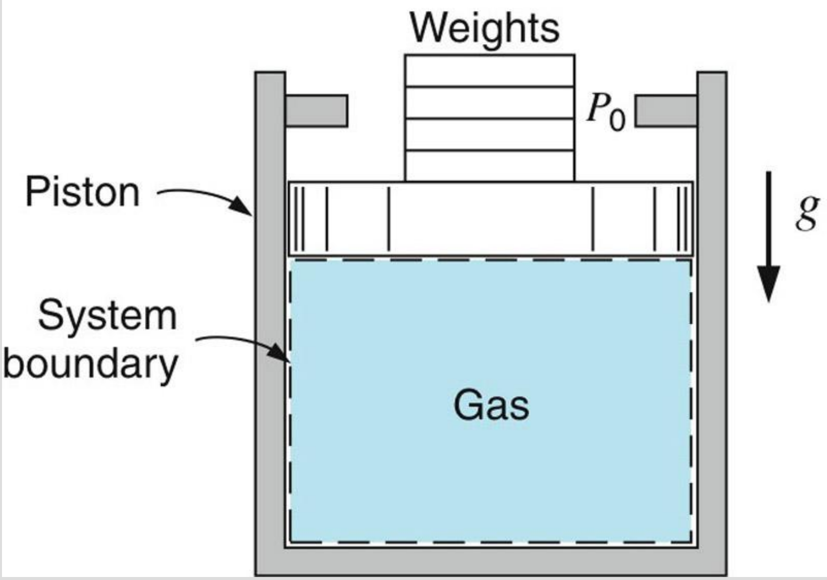
Closed and Open System

A system of fixed mass is called a ***Closed System***, or *Control Mass*, and a system that involves mass transfer across its boundaries is called an ***Open System***, or *Control Volume*.



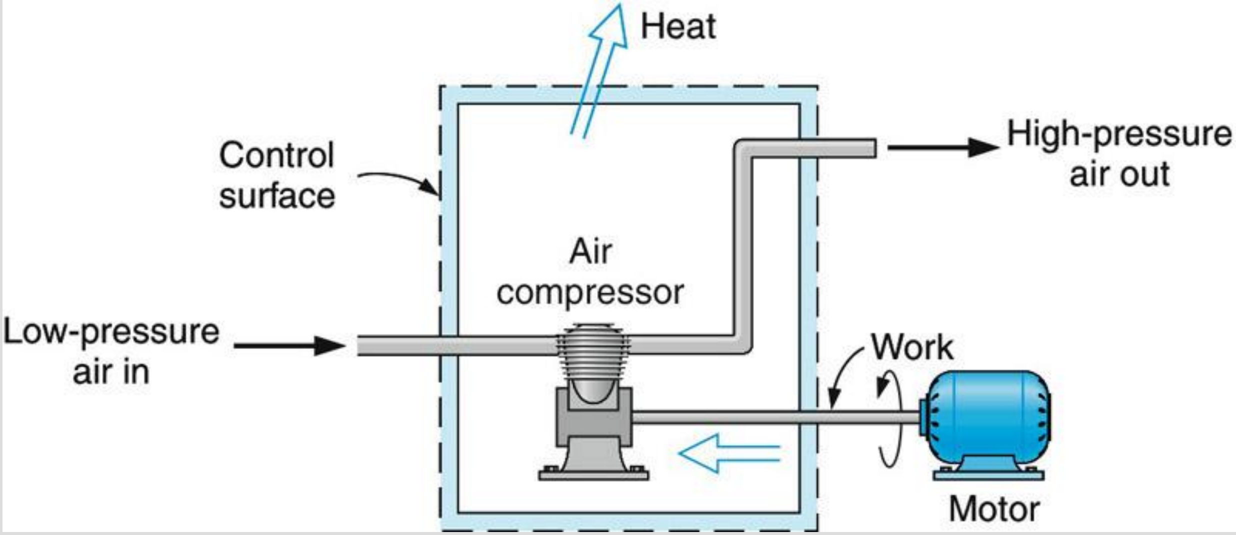


Closed and Open System



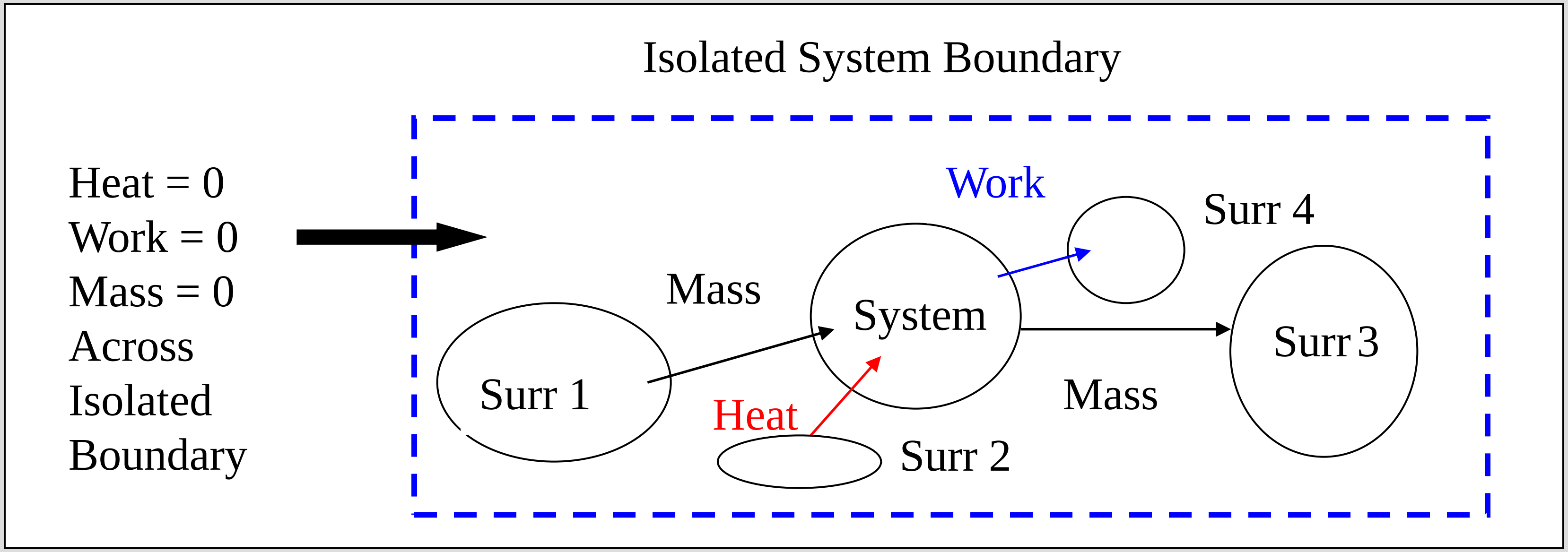
Control Mass

vs. *Control Volume*.



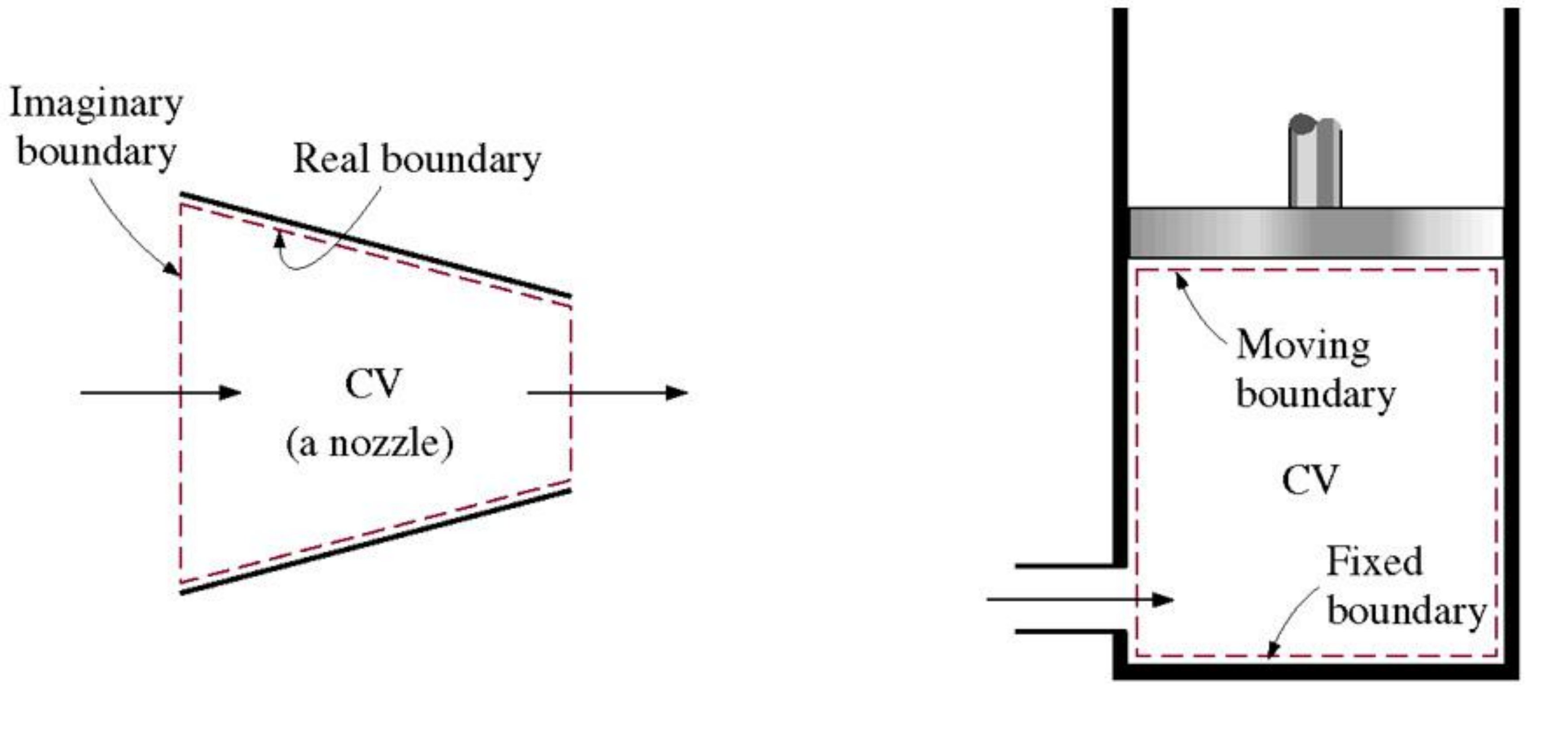
Isolated System

An ***Isolated System*** is a general system of fixed mass where no heat or work may cross the boundaries. An isolated system is a closed system with no energy crossing the boundaries and is normally a collection of a main system and its surroundings that are exchanging mass and energy among themselves and no other system.



Control volume

A control volume may involve fixed, moving, real, and imaginary boundaries.

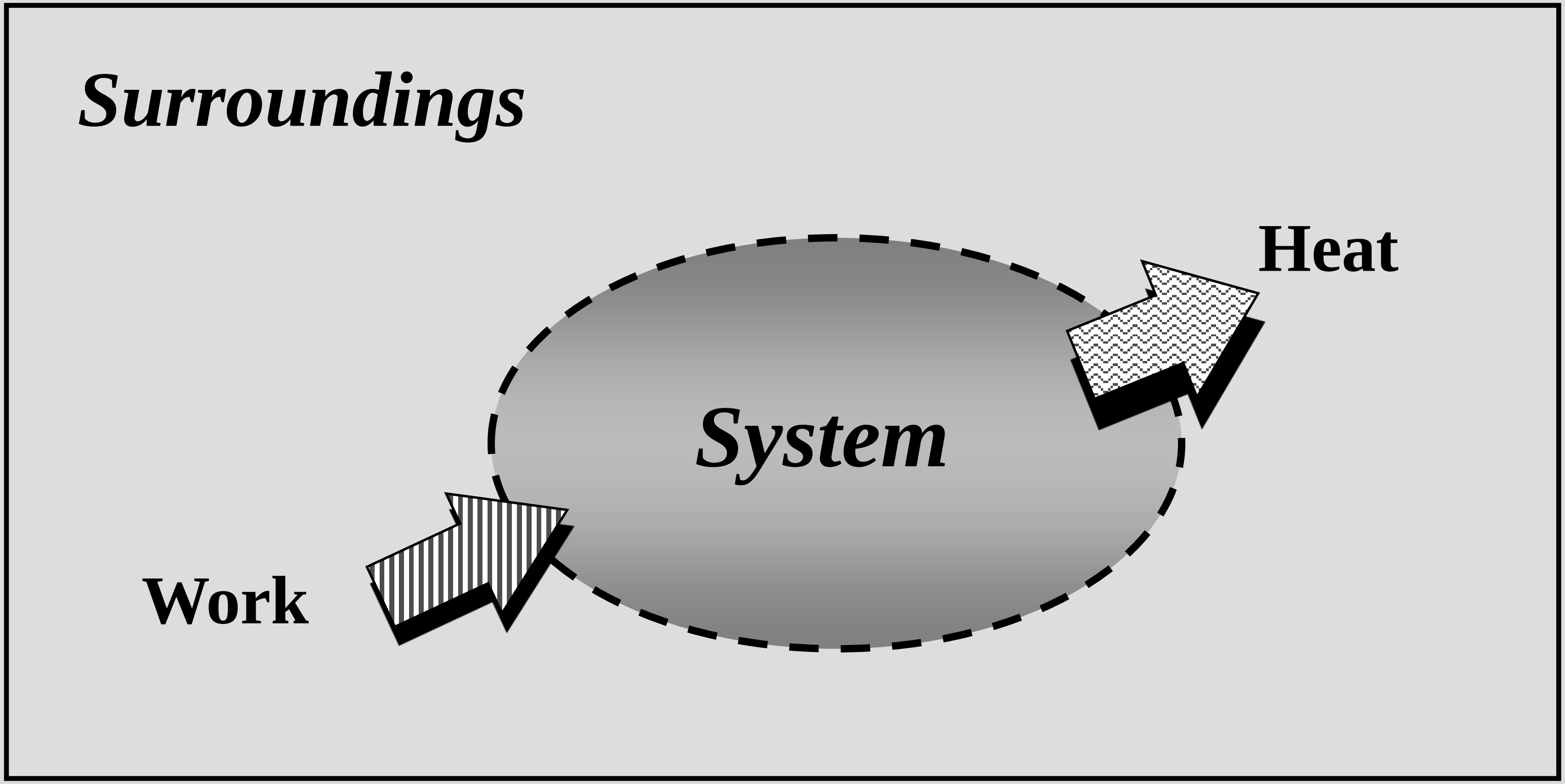


(*a*) A control volume with real and imaginary boundaries

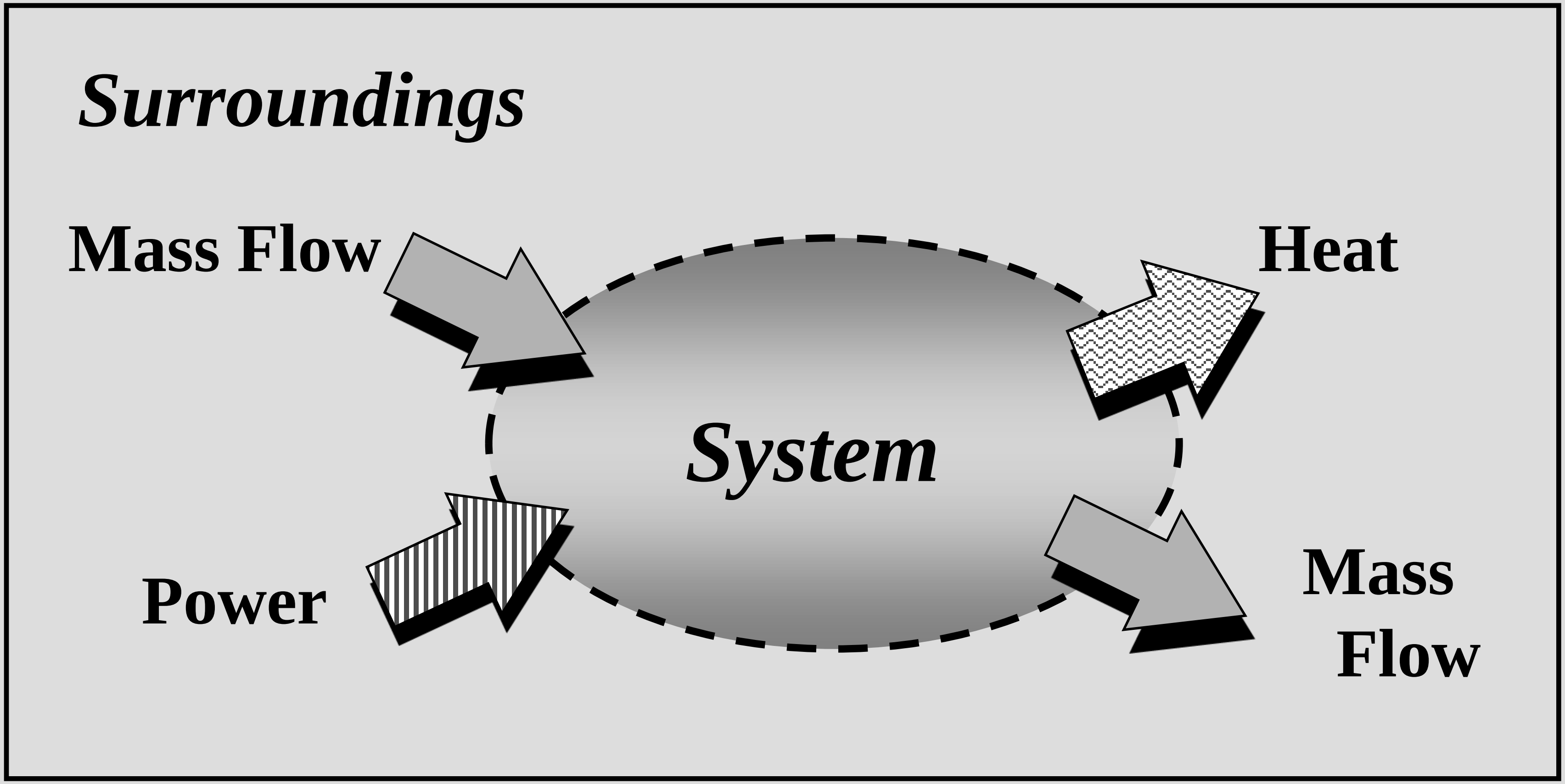
(*b*) A control volume with fixed and moving boundaries

Interactions between system and surroundings...

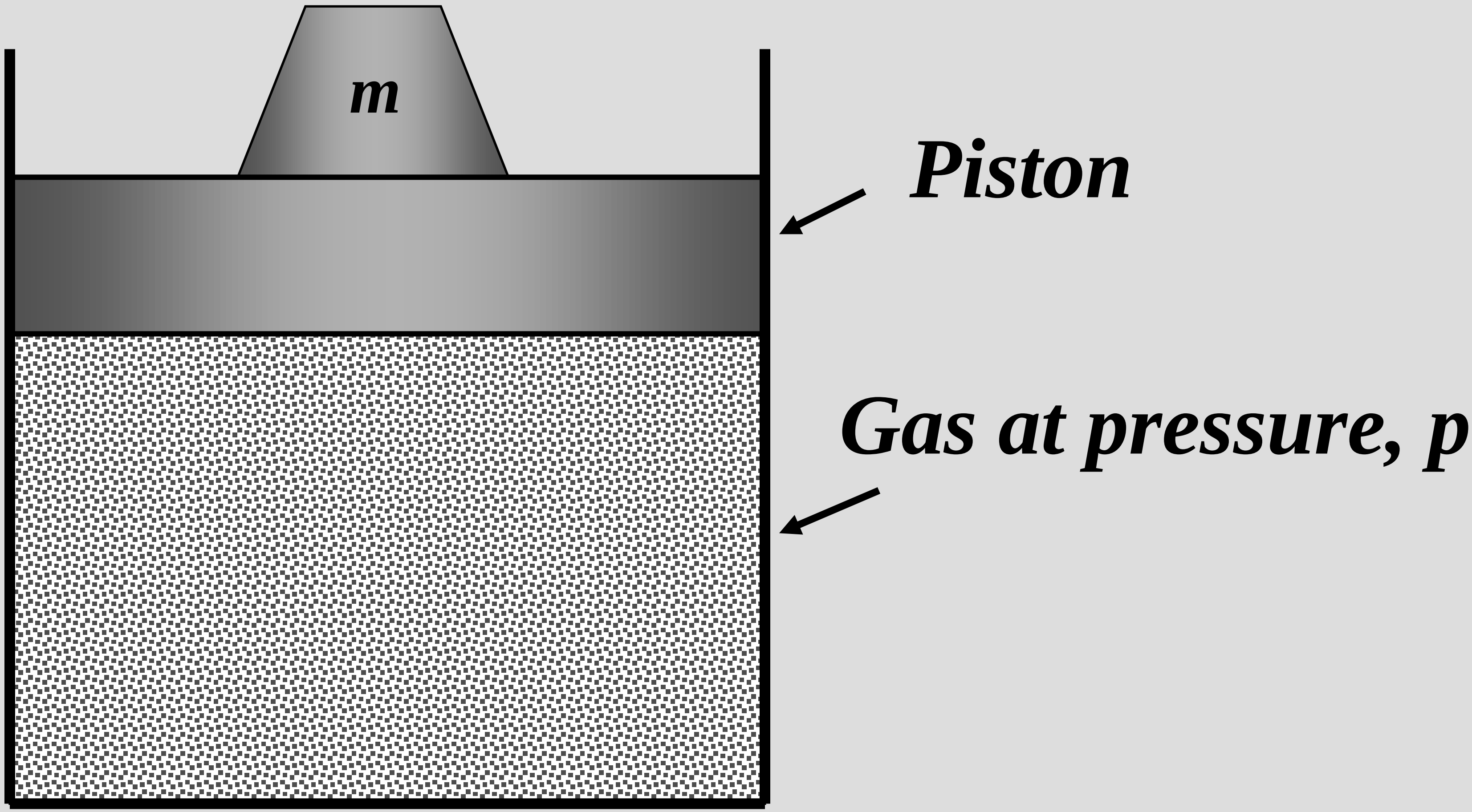
Closed system - summary



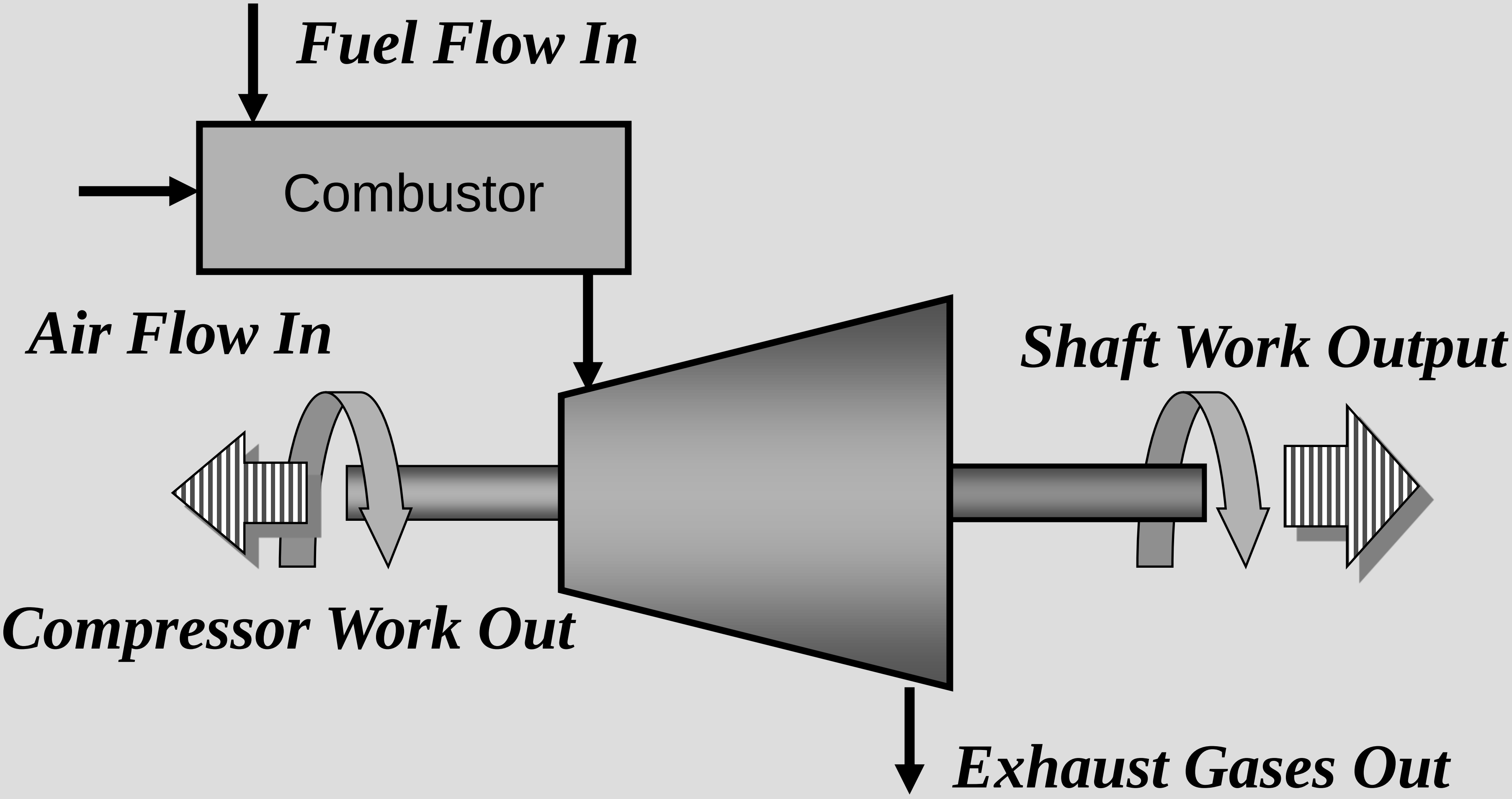
Open system - summary



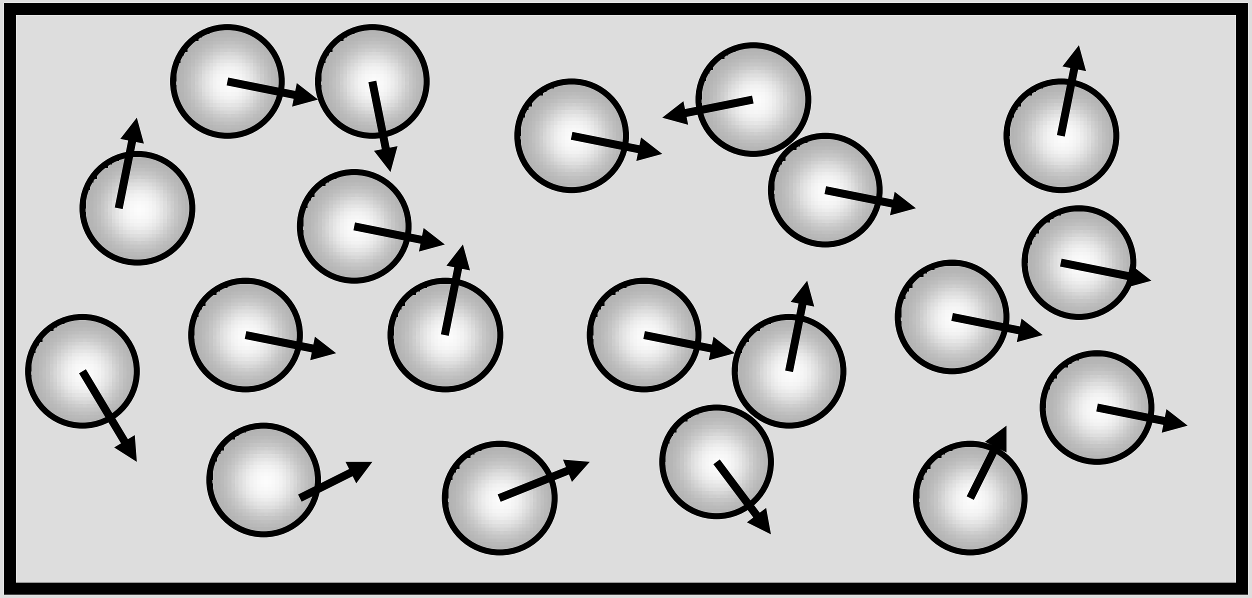
Example: Piston and cylinder - a closed system



Example: The gas turbine engine - an open system

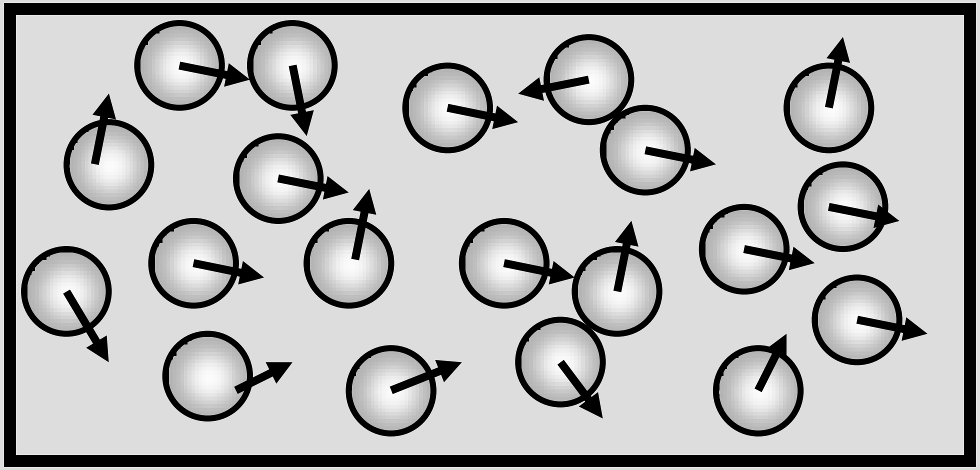


Macroscopic vs. microscopic viewpoints...



A collection of atoms within a container, each with a unique velocity.

Energy in a microscopic description

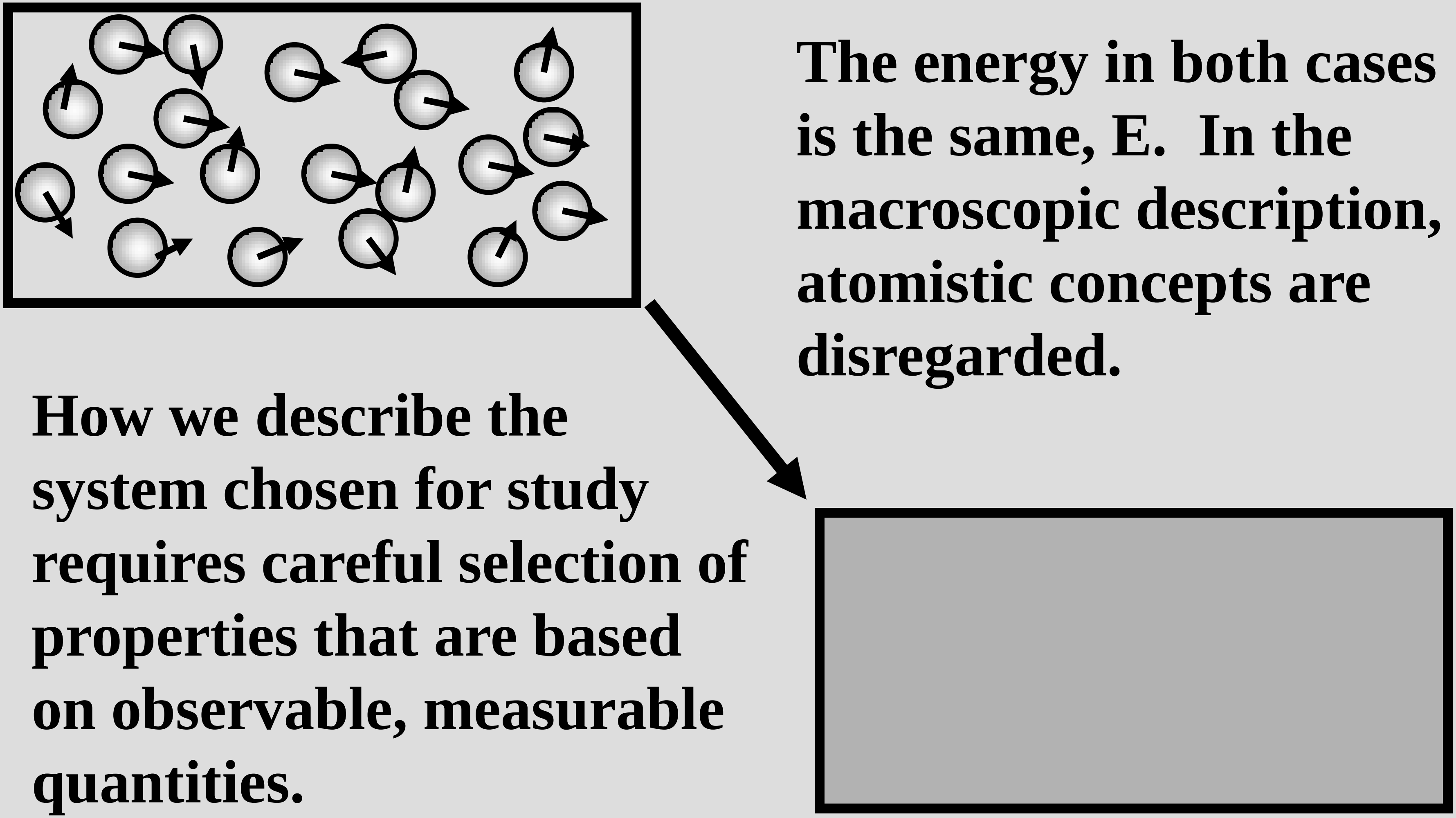


Energy of each atom $= e = \frac{1}{2} m |\underline{V}|^2$

Number of atoms = N

Total Energy = $eN = \frac{N}{2} m |\underline{V}|^2 = \sum_{i=1}^{N} ke_i$

The macroscopic description



The energy in both cases is the same, E. In the macroscopic description, atomistic concepts are disregarded.

How we describe the system chosen for study requires careful selection of properties that are based on observable, measurable quantities.

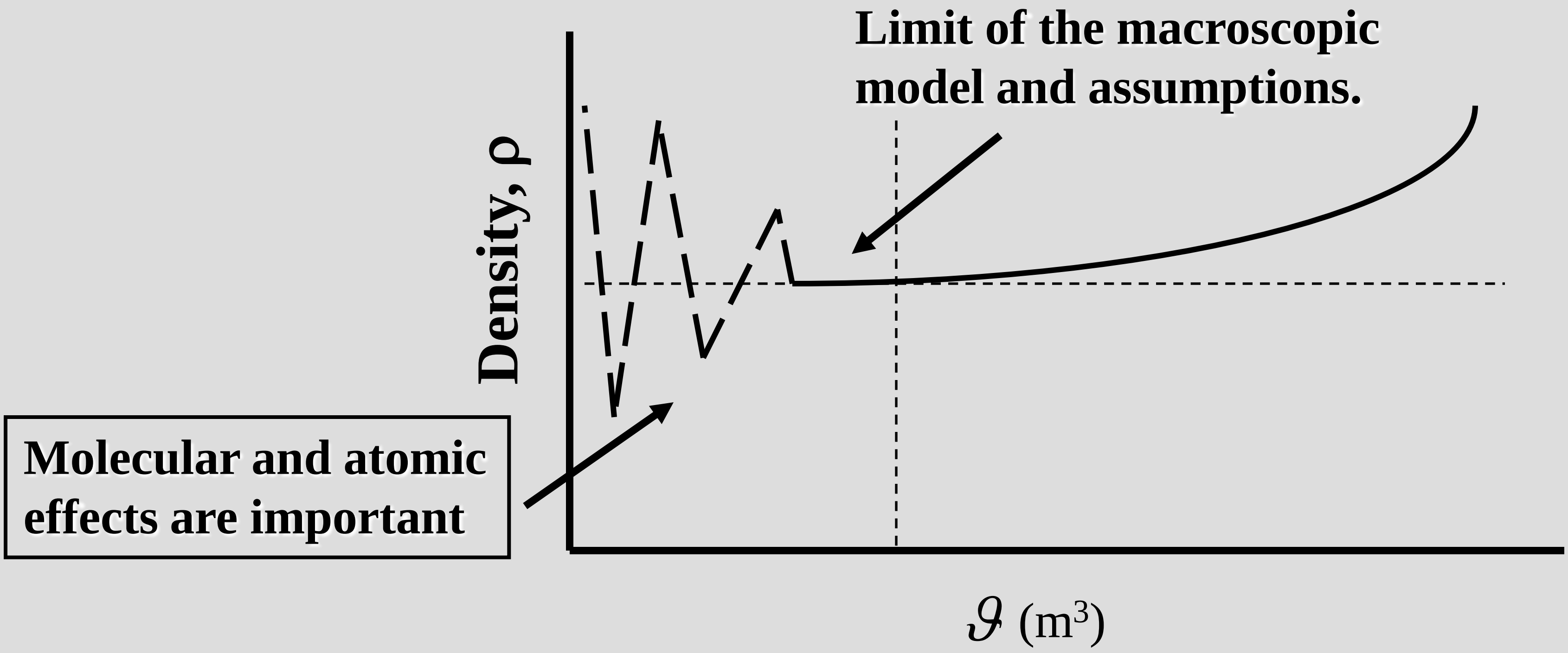
The macroscopic viewpoint...

State of a thermodynamic system. → **Enumeration of all of its properties.**

In macroscopic thermodynamics, the properties of system are assigned to the system as a whole.

Properties in macroscopic thermodynamics

$$\rho = \lim_{\Delta\vartheta \to 0}\left(\frac{\Delta m}{\Delta\vartheta}\right) \equiv \frac{1}{\upsilon} = \frac{1}{specific\ volume}$$



Density of common substances