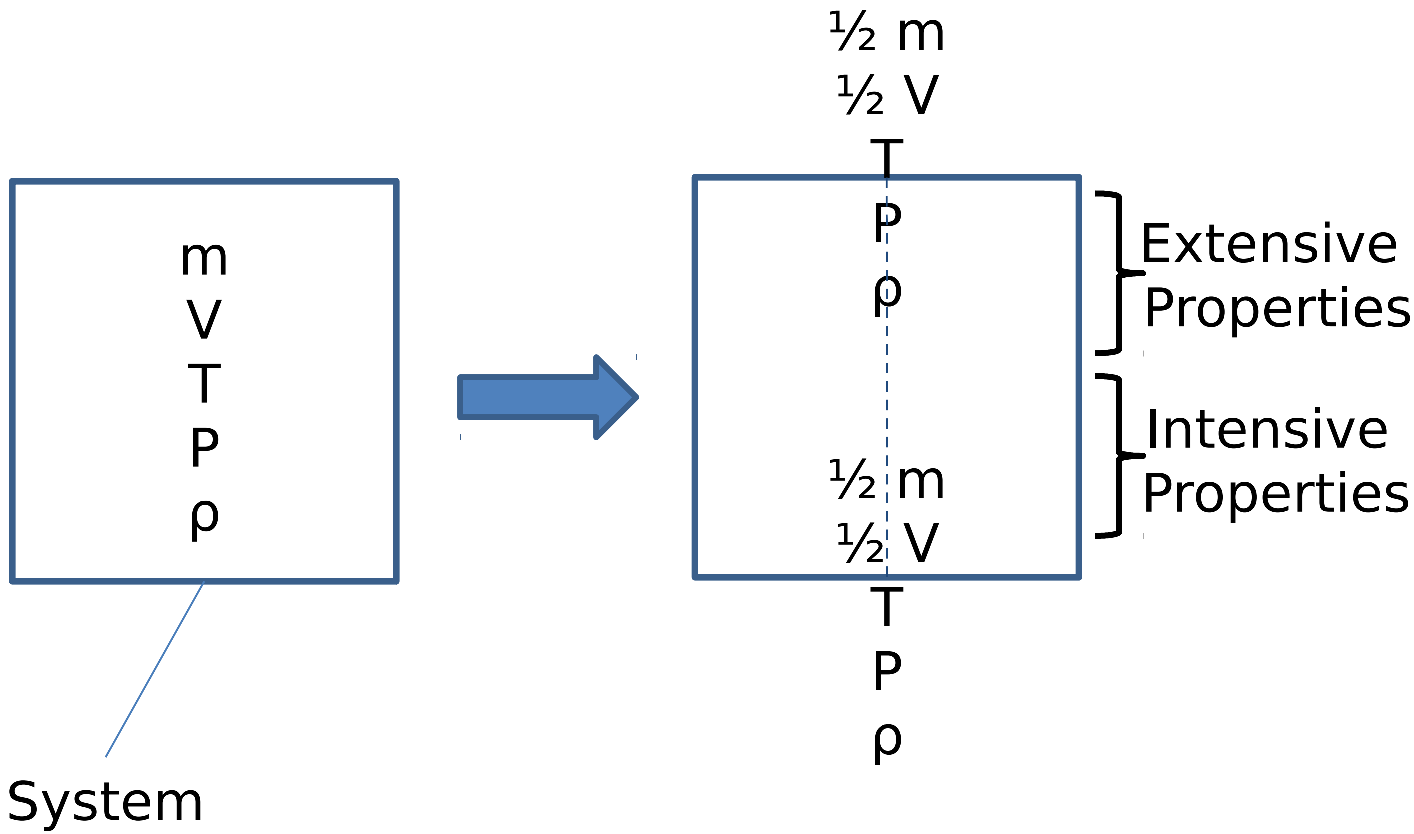
- Recap: **Lecture 1, 06/01/2014: 1130-1230 hrs.**
  - Course contents
  - Evaluation scheme, grading scheme
  - Attendance policy
  - Objectives of the course
  - Introduction to Thermodynamics
  - Macroscopic and microscopic approach
  - Continuum
  - System and control volumes
    - Closed, open and isolated systems

Property

- Property: Any characteristic of a system
  - Temperature, pressure, density, mass…
- Intensive property: independent of mass
  - Temperature, pressure
- Extensive property: dependent on size or mass of the system
  - Mass, volume, momentum
- Specific properties: extensive properties per unit mass
  - specific volume ($v=V/m$), specific energy ($e=E/m$)

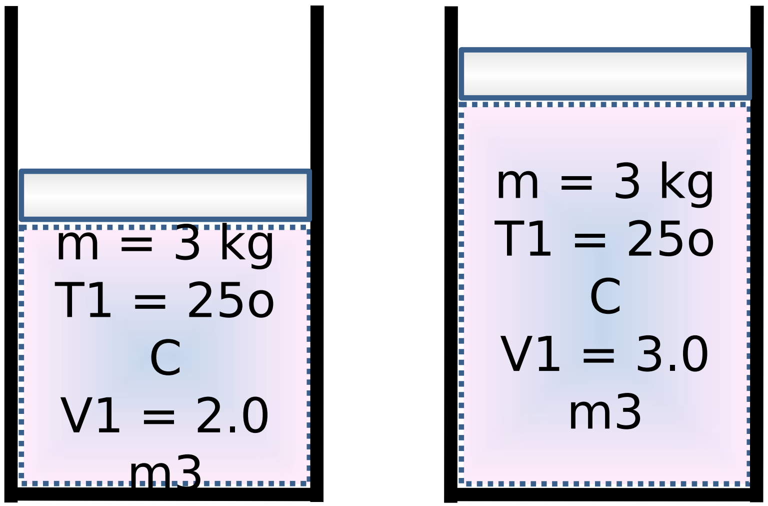
Properties of a system



State of a System

- State: a set of properties that completely defines the condition of a system.
- It gives a complete description of the system.
- At a given state, all the properties of a system have fixed values.
- Any operation in which one or more properties of a system change is called a change of state.

State of a System



(a) State 1

(b) State 2

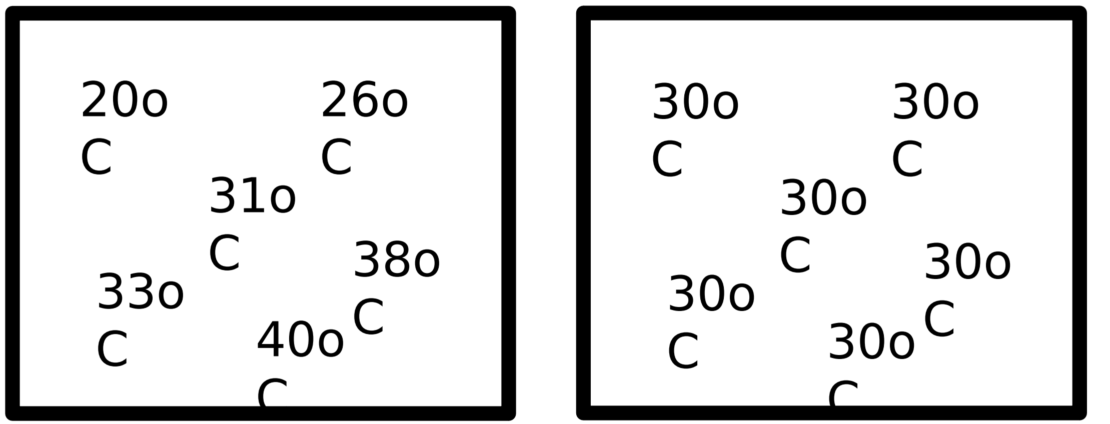
A system at two different states

Equilibrium

- Thermodynamics deals with equilibrium states.
- The word equilibrium implies a state of balance.
- In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- A system in equilibrium experiences no changes when it is isolated from its surroundings.

- There are many types of equilibrium.
- These are mechanical equilibrium, thermal equilibrium, chemical equilibrium and phase equilibrium.
- A system is not in thermodynamic equilibrium unless the conditions of all the relevant types of equilibrium are satisfied.
- A system in thermodynamic equilibrium does not deliver any useful work.

- Thermal equilibrium: if the temperature is the same throughout the system
- Mechanical equilibrium: if the pressure is the same throughout the system
- Chemical equilibrium: if the chemical composition does not change with time, i.e., no chemical reactions occur
- Phase equilibrium: when the mass of each phase reaches an equilibrium level and stays there

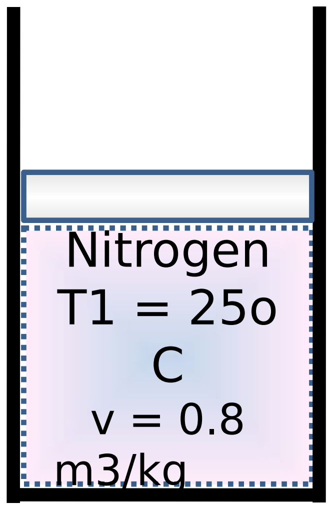


(a) Before

(b) After

A closed system reaching thermal equilibrium

State Postulate

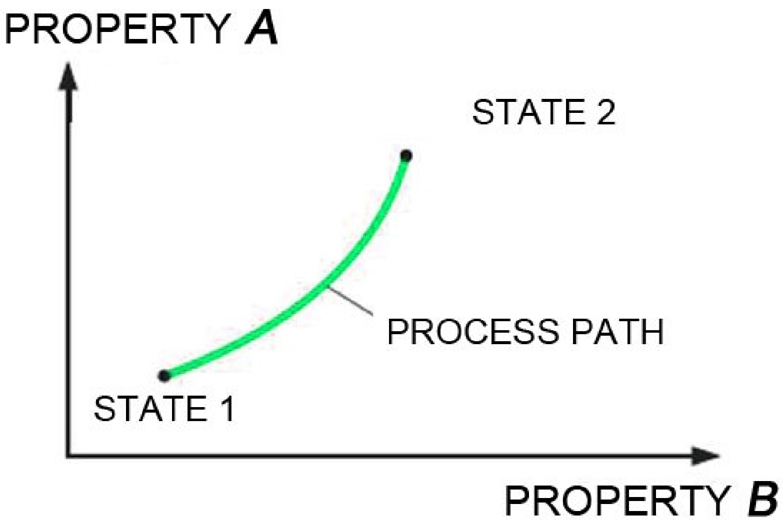


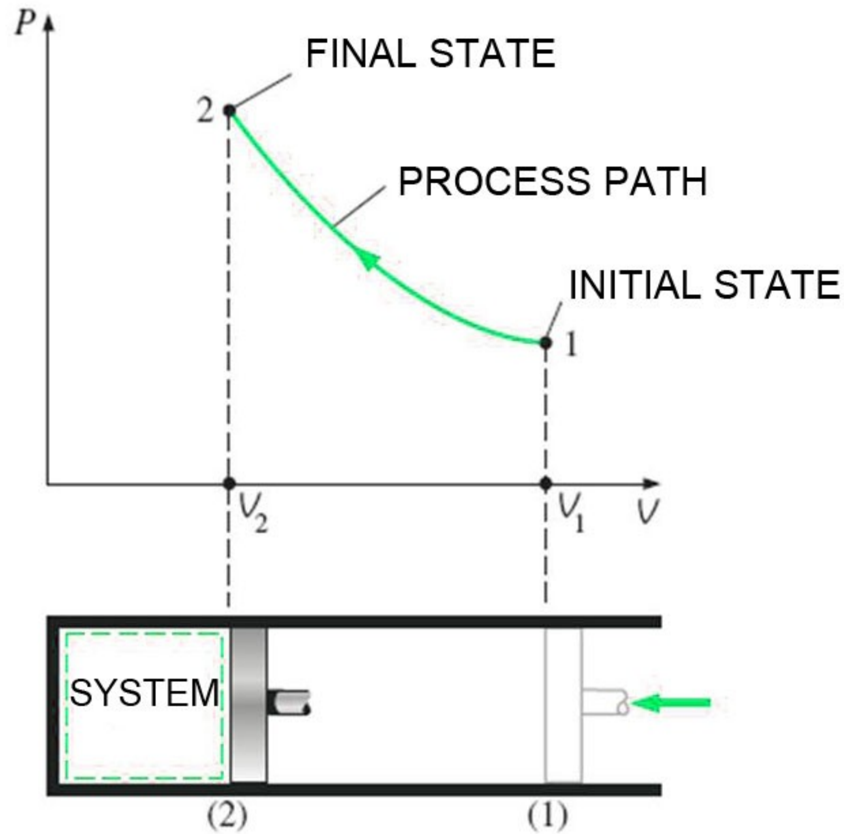
- The state of nitrogen gas, for example, can be fixed by two independent, intensive properties.
- Temperature and specific volume are independent, intensive properties.
- But temperature and pressure are not independent (in case of phase change process), though are intensive properties.

Process, path and cycle

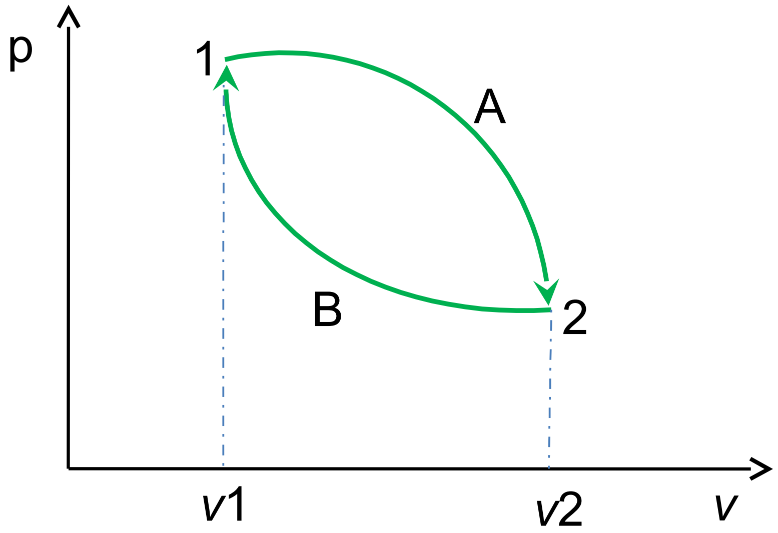
- Process: Any change that a system undergoes from one equilibrium state to another.
- Path: The series of states through which a system passes during a process.
- Cycle: If the system returns to its initial state at the end of the process
  - That is, for a cycle the initial and final states are identical.

Process, path and cycle





Cycle



Types of processes

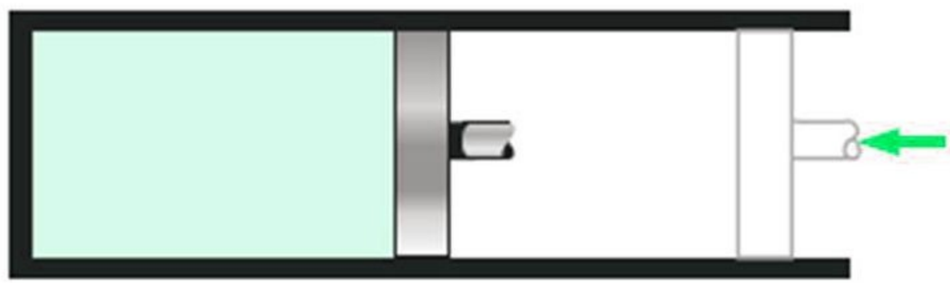
- Usually during a process, we allow one of the properties to remain a constant.

- Isothermal process: constant temperature
- Isobaric process: constant pressure
- Isochoric process: constant volume
- Isentropic process: constant entropy (?)
- Isenthalpic process: constant enthalpy (?)

Quasi-static processes

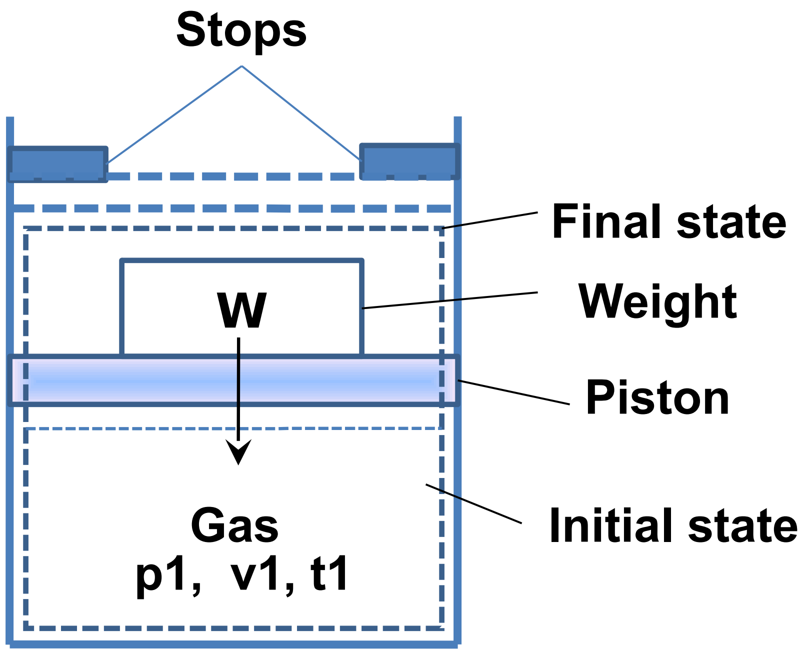
- When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times: Quasi-static or Quasi-equilibrium process
- The process proceeds slow enough to allow the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts.

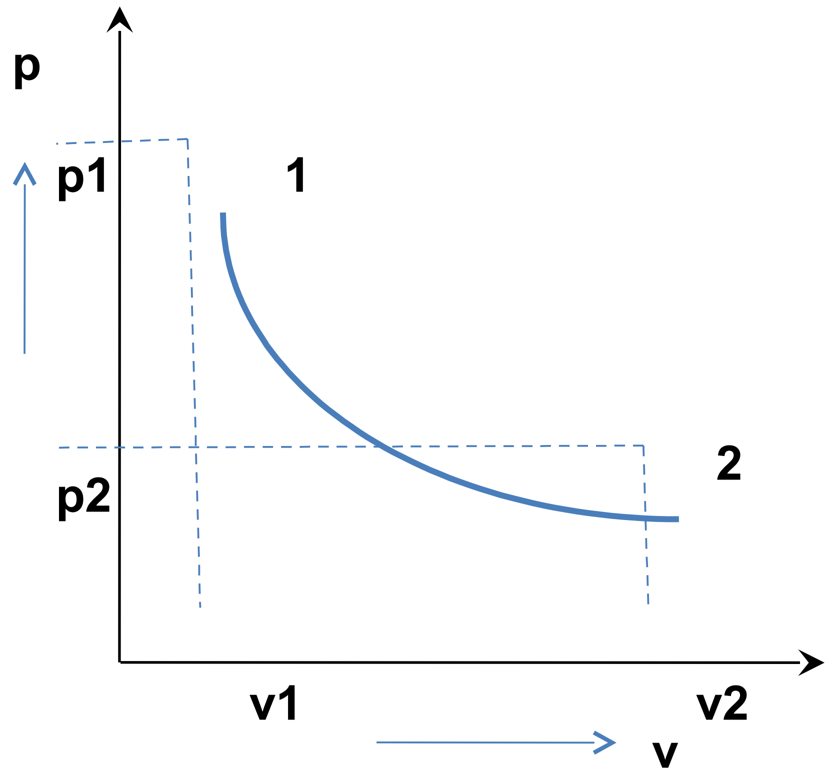
SLOW COMPRESSION
(QUASI-EQUILIBRIUM)



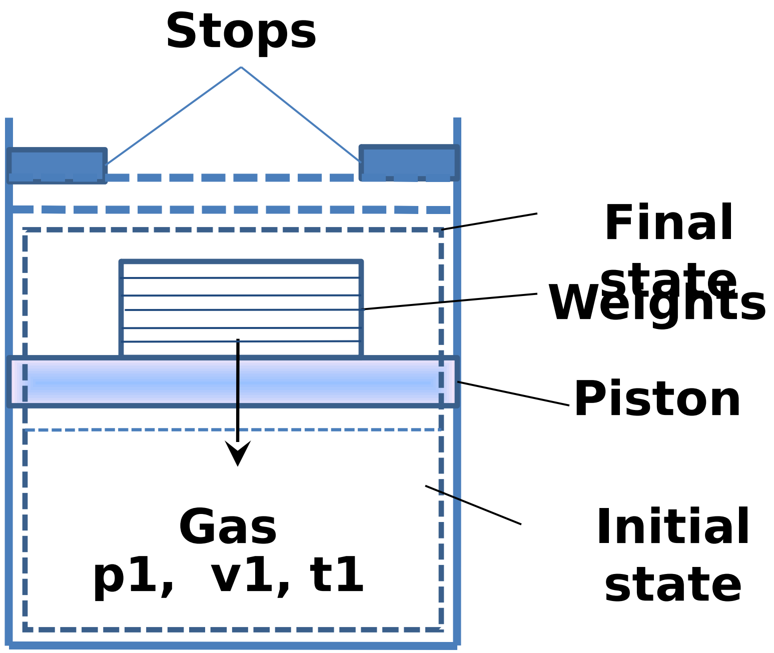
VERY FAST EQUILIBRIUM
(NON QUASI-EQILIBRIUM)

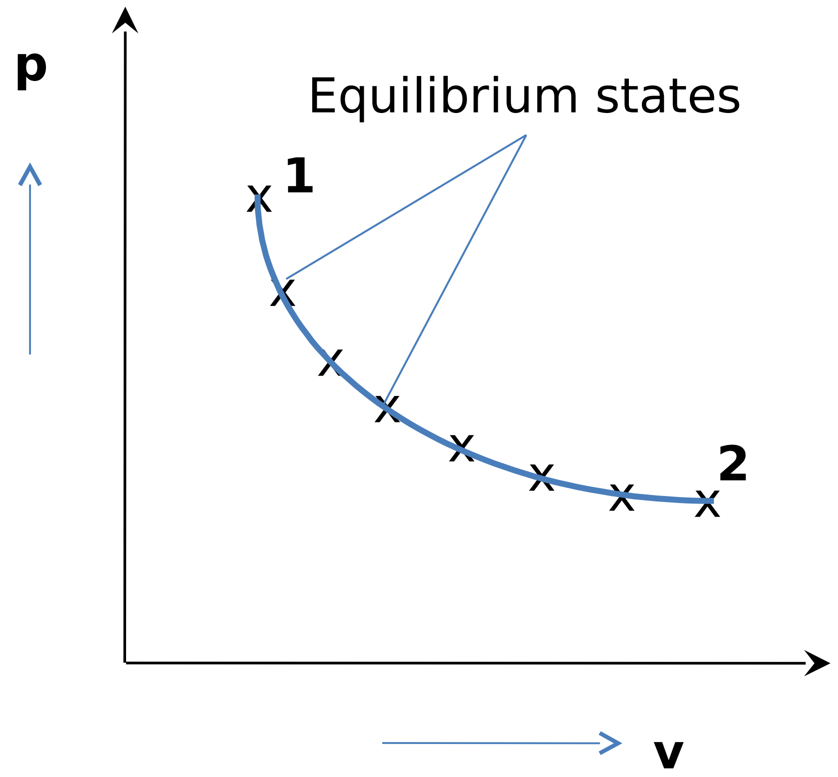
Quasi-static processes





Quasi-static processes





Quasi-static processes

- Engineers are interested in quasi-static processes because
  - they are easy to analyse
  - work-producing devices deliver maximum work when they operate on quasi-static processes
- Quasi-static processes serve as standards to which actual processes can be compared

Energy

- Energy can exist in numerous forms such as thermal, mechanical, kinetic, potential, electric, magnetic, chemical, and nuclear
- The sum total of the above: **Total energy, *E***

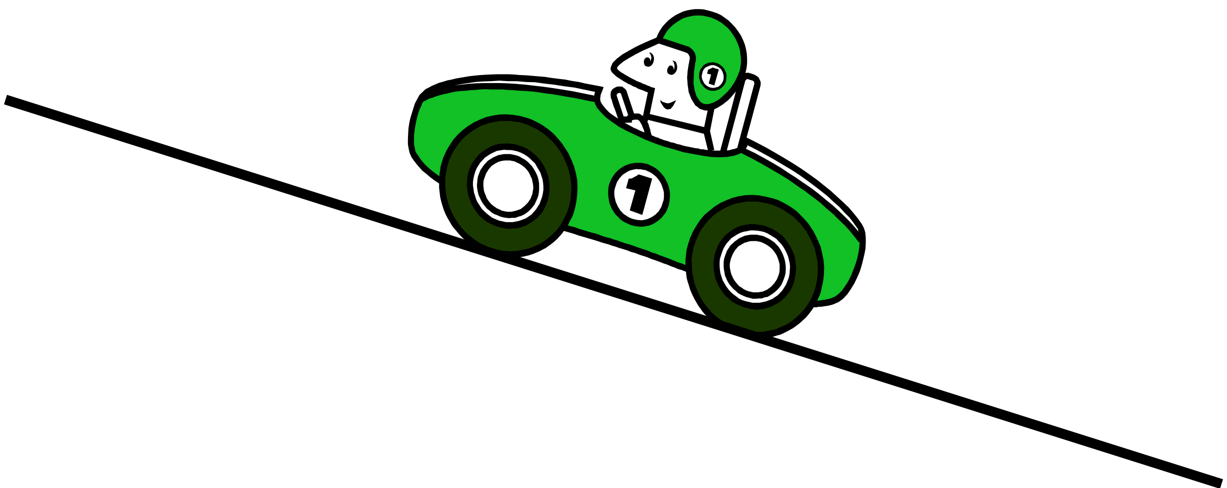
$$e = E/m \ kJ/kg$$

- Thermodynamics provides no information about the absolute value of the total energy.
- It deals only with the change of the total energy, which is what matters in engineering problems.

Energy

- Forms of energy:
  - Macroscopic energy: Energy that a system possesses as a whole with respect to some outside reference frame, eg: Kinetic Energy, Potential Energy
  - Microscopic energy: These are related to the molecular structure of a system and the degree of the molecular activity and are independent of the outside reference frames
  - Sum of all microscopic forms of energy of a system: Internal energy, U (kJ) or $u = U/m$ (kJ/kg)

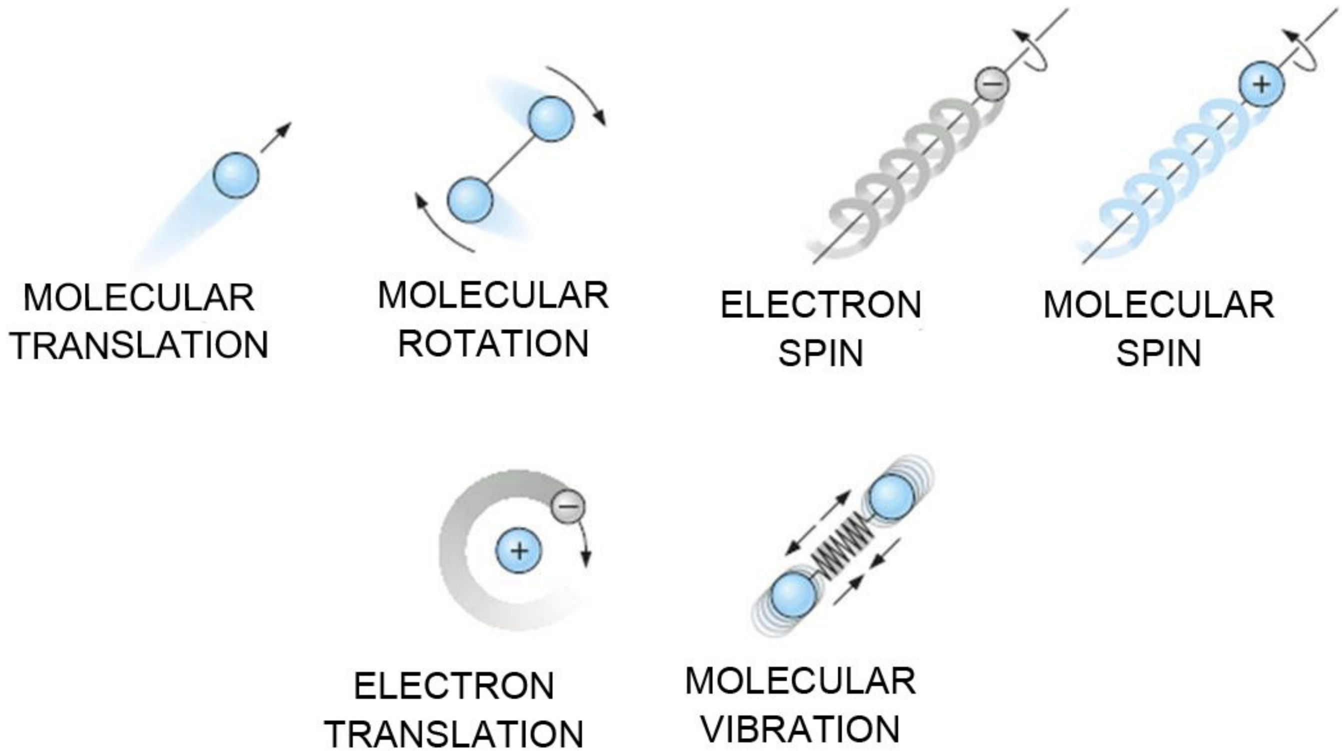
Macroscopic energy



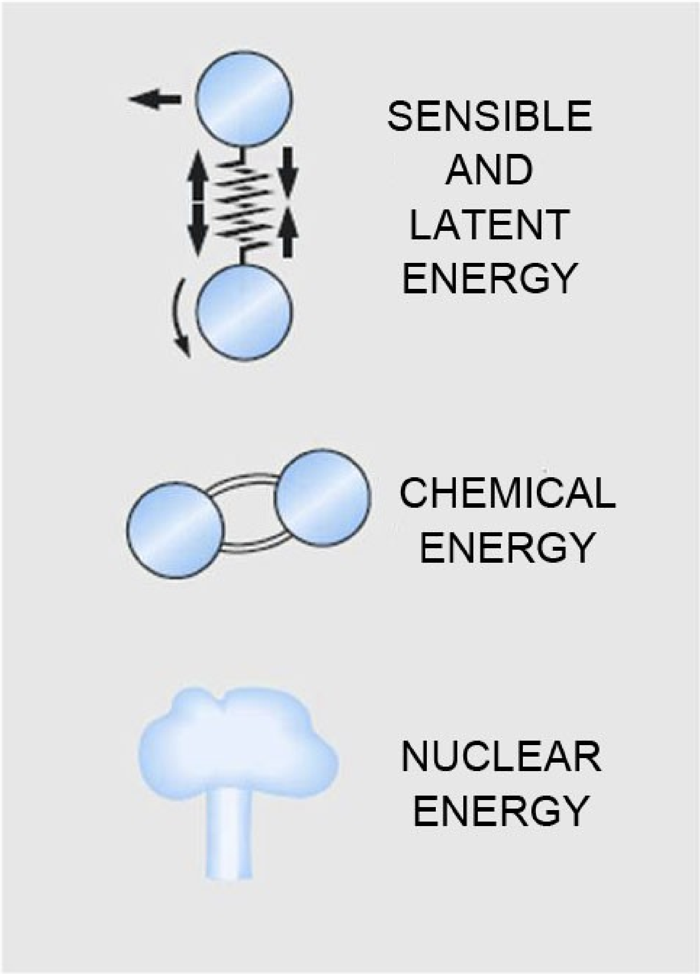
The macroscopic energy, KE and PE, of an object changes with velocity and elevation.

Internal energy

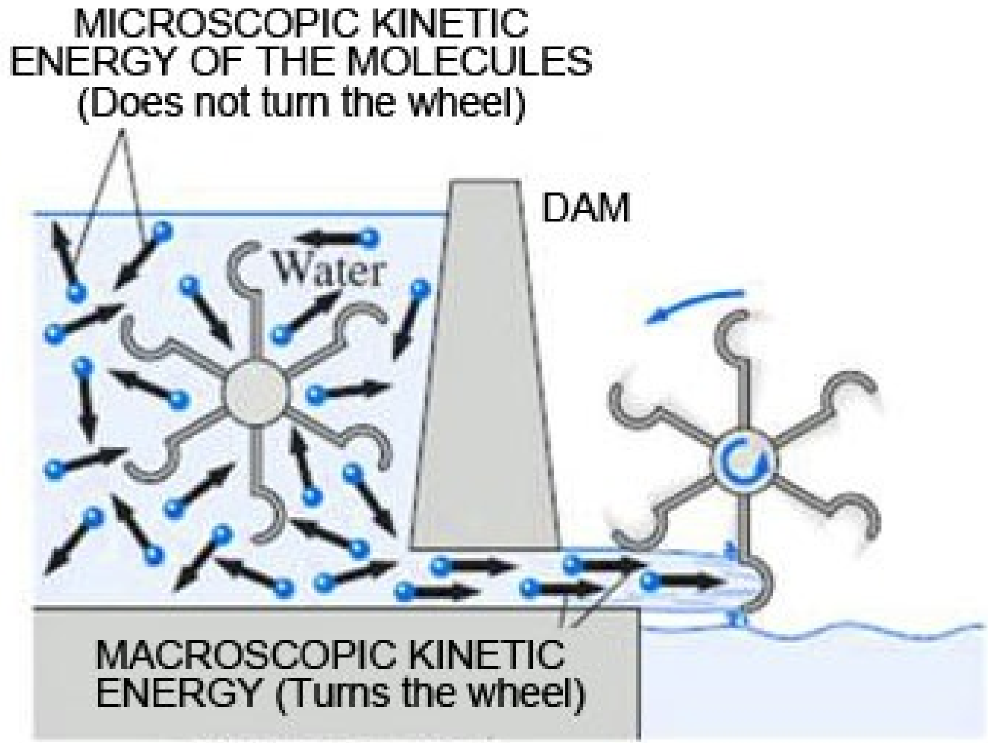
- Sensible energy: Part of the internal energy associated with kinetic energy of molecules
  - Rotational KE, translational KE, vibrational KE
- Latent energy: Internal energy associated with phase change of a system
- Chemical energy: Internal energy associated with the atomic bonds in a molecule
- Nuclear energy: Tremendous amount of energy associated with the strong bonds within the nucleus of the atom



The various forms of microscopic energies that make up sensible energy.



The internal energy of a system is the sum of all forms of the microscopic energies.



The *macroscopic* kinetic energy is an organized form of energy and more useful than the disorganized *microscopic* kinetic energies of the molecules

Kinetic and Potential energies

- Kinetic energy, KE, of a system:

$$KE = \frac{mV^2}{2} \text{ (kJ)} \quad \text{or,} \quad ke = \frac{V^2}{2} \text{ (kJ/kg) on a unit mass basis}$$

- Potential energy, PE, of a system:

$$PE = mgz \text{ (kJ)} \quad \text{or,} \quad pe = gz \text{ (kJ/kg) on a unit mass basis}$$

Total energy of a system

- In the absence of magnetic, electric, and surface tension effects, the total energy of a system consists of the kinetic, potential, and internal energies

$$E = U + KE + PE = U + \frac{mV^2}{2} + mgz \quad \text{(kJ)}$$

or, on a unit mass basis

$$e = u + ke + pe = u + \frac{V^2}{2} + gz \quad \text{(kJ/kg)}$$

Total energy of a system

- Closed systems whose velocity and elevation of the center of gravity remain constant during a process are frequently referred to as stationary systems.

- The change in the total energy *E* of a stationary system is identical to the change in its internal energy *U*.