Thermodynamics

Thermodynamics – the science that deals with energy and its relation to matter, and the laws governing their interactions.

Thermodynamics is most general because every technological system involves the utilization of energy and matter.

Historically, the science of thermodynamics was developed to provide a better understanding of devices, known as heat engines, that absorb heat from a high temperature source and produce useful work. For this reason, in many earlier books the following definition of thermodynamics appears:

"Thermodynamics is the science that deals with relations between heat and work."

Definition of Engineering Thermodynamics

Engineering thermodynamics is the subject that deals with the study of the science of thermodynamics and the usefulness of this science in the engineering design of processes, devices, and systems involving the effective utilization of energy and matter for the benefit of mankind.

Ref: Eng. Thermodynamics - fundamentals & applications - Francis F Huang.
Macmillan Publishing Co. Inc. New York. 1976

Macroscopic approach	Microscopic approach
Macro = big	Micro = small
1. In this approach a certain quantity of matter is cosidered without taking into account the events occuring at molecular level. This approach is concerned with gross or overall behaviour.	This approach considers that the system is made up of a very large number of discrete particles known as molecules. These molecules have different velocities and energies. The values of these energies are constantly changing with time.
2. Only a few properties are needed to describe the system.	Large no. of variables are needed to describe the system, so the approach is complicated.
3. The values of the system properties are their average values. e.g. pressure of a gas is the average value of the pressure exerted by millions of individual molecules. e.g temperature of a gas is the average value of the translational kinetic energies of millions of individual molecules.	The properties like velocity, momentum, impulse, kinetic energy, force of impact, etc. which describe the molecular behaviour cannot be easily measured by instruments.
4. The changes in properties can be felt by our senses.	Our senses cannot feel changes in these properties.
5. Macroscopic system requires simple mathematical formulae in order to analyze them.	Advanced statistical and mathematical methods are needed to explain the changes in the system.

Some basic concepts and definitions

In mechanics, if we want to study the motion of a body, we must draw the "free body" and identity all the forces exerted on it by other bodies before we proceed to apply the governing equations of motions. In other words, we must first understand how other bodies interact with the body that we want to study.

Likewise, if we wand to study the behavior of a particular thermodynamic system, we must be able to identify the other thermodynamic systems that interact with the system in question before we apply the governing equations in thermodynamics.

- System : any collection of matter or any region in space bounded by a closed surface or wall.
  - The wall may be a real one, like that of a tank enclosing a certain amount of fluid.
  - The wall may also be imaginary, like the boundary of a certain amount of fluid flowing along a pipe.
- Surroundings : All other systems outside the wall that interact with the system in question are known as the surroundings.

Depending on the nature of the wall involved, we can classify a thermodynamic system as a closed system, an open system, or an isolated system.

- In a closed system, the wall involved is impermeable to matter. i.e. a closed system can have no material exchange with its surroundings, and consequently its mass must remain constant. On the other hand, a closed system can exchange energy with its surroundings in terms of heat and work.

- In an open system, there will be material flow across the boundary. In addition, there could also be heat flow and work flow across the boundary.

- In an isolated system, there can be absolutely no interaction with its surroundings. The wall involved is not only impermeable to matter; it is also impermeable to any form of energy. An isolated system may therefore be defined as an assembly of subsystems with any possible interaction between matter and energy restricted to the subsystems within the assembly. Any system + its surroundings taken together would consitute an isolated system.

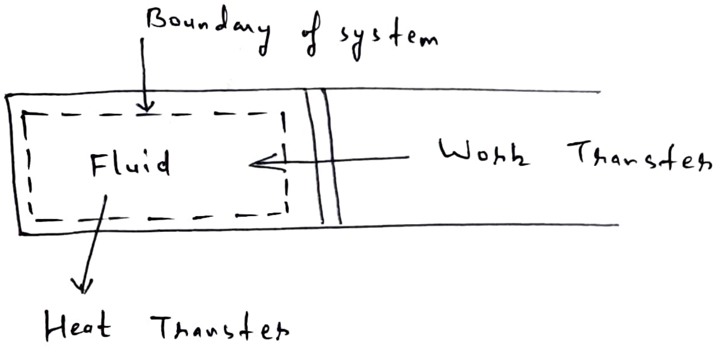

Fig: Closed system --- fluid inside the cylinder of a piston-cylinder apparatus.

System properties

Intensive	Extensive
(Independent of the amount of material in the system)	(Proportional to the mass of a system)
- They are not additive.	- They are additive.
e.g. Pressure, Temp., Density	e.g. Volume, energy, entropy, mass, weight

Thermodynamic Processes

When a collection of matter experiences a change from one equilibrium state to another equilibrium state, it is said to have undergone a process.

- Isothermal process :- a constant temperature process
- Isobaric process :- a constant pressure process
- Isometric process :- a constant volume process

(may be recognized from names)

- Adiabatic process :- A process in which no heat crosses the system boundary in either direction is called an adiabatic process.

Cyclic process or Cycle :-

A cycle is simply a sequence of processes that a system undergoes in such a manner that its initial state and its final state are identical. In other words, the net change in any property of the system is zero for a cycle.

Mathematically,

$$\oint dX = 0$$

where X is any property and the symbol $\oint$ indicates integration around a cycle.

Equilibrium

Quasi-static Process :-

If a process is carried out in such a manner that at every instant the system departs only infinitesimally from an equilibrium state, the process is called quasi-static (sometimes called quasi-equilibrium).

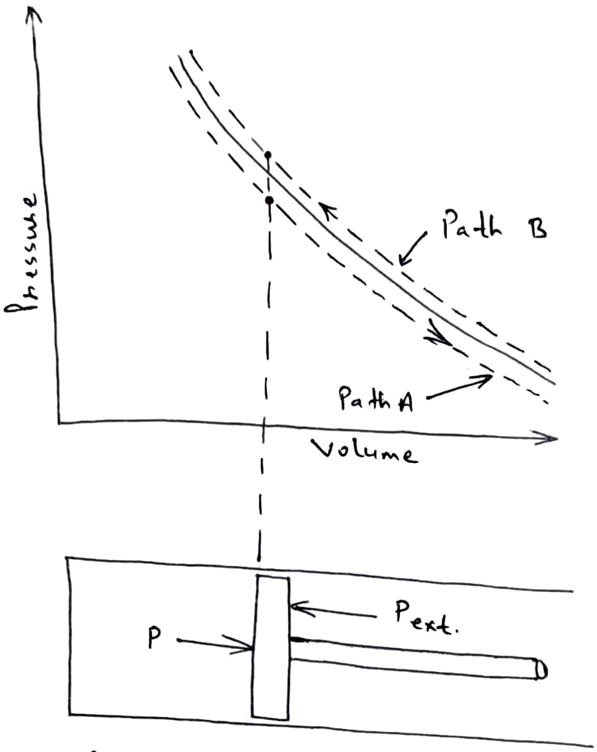

Fig: Quasi-static Expansion and Compression of a gas

Consider a gas in a cylinder provided with a movable piston as shown in figure. If the external pressure P_{ext} is maintained infinitesimally less than the gas pressure P, the gas will expand quasi-statically following path A.

If the external pressure P_{ext} is maintained infinitesimally greater than the gas pressure P ($P_{ext} > P$), the gas will be compressed quasi-statically following path B.

In the limit these two processes follow the same path in opposite directions. Thus a quasi-static process is reversible, or more correctly, internally reversible.

A quasi-static process is an ideal process. It is approximately realized by making the change very slowly. All real-processes are not quasi-static because they take place with finite differences of pressure, temp, and so on, between system and surroundings.

Equilibrium

Reversible Process

A process is <u>reversible</u> if, after it has been carried out, it is possible by any means whatsoever to restore the system and the surroundings involved in the interaction to exactly the same ~~system~~ states they were in before the process.

- This implies that, if a process is reversible, it is possible to undo it in such a manner that there will be no trace anywhere of the fact that the process occurred.

- Real processes are all irreversible processes, although some are less irreversible than others.

Reasons for irreversibility:

(1) Lack of equilibrium during the process

(2) Presence of friction of any kind, be it mechanical friction, fluid friction or electrical resistance.

Fluid Statics

- $P = \rho g h$ (gage pressure)
  $= \gamma h$ (gage pressure)

- Pressure head,

$$h = \frac{P}{\rho g} = \frac{P}{\gamma}$$

- Absolute pressure uses absolute zero as its base (zero reading). Absolute zero is the lowest possible pressure and it means the perfect vaccum.

- Gage pressure is measured with atmospheric pressure as its base.

- Standard atmospheric pressure

$$760 \text{ mm Hg} \ (29.9 \text{ inch Hg}) \equiv 14.7 \text{ Psi} \equiv 1.01355 \times 10^5 \ \frac{N}{m^2} \ (= Pa)$$

$$\equiv 101.3 \text{ kPa}$$

- Barometer is used to measure atmospheric pressure.