BASIC CONCEPTS OF THERMODYNAMICS

THERMODYNAMICS :

Thermodynamics can be defined as the study of energy, energy transformations and its relation to matter. The analysis of thermal systems is achieved through the application of the governing conservation equations, namely *Conservation of Mass*, *Conservation of Energy* (1st law of thermodynamics), the 2nd law of thermodynamics and the property relations.

Thermodynamic Systems

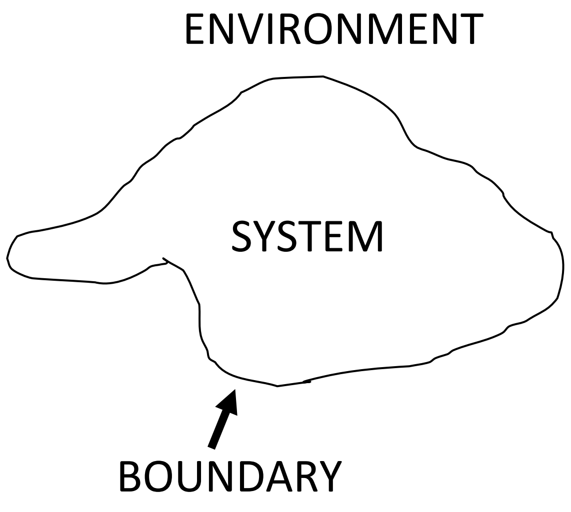
A thermodynamic *system* is defined as a quantity of matter or a region in space chosen for study. A real or imaginary ***boundary*** separates the system from the rest of the universe, which is referred to as the ***environment or surrounding***.

Surroundings or Environment

Everything external to the system.

Boundary

Surface that separates the system from the surrounding. It may be **fixed** or **movable**



A useful classification of thermodynamic systems is based on the nature of the boundary and the flows of matter, energy and entropy through it. There are three kinds of systems depending on the kinds of *exchanges* taking place between a system and its environment:

***Isolated* systems:** not exchanging heat, matter or work with their environment. An example of an isolated system would be an insulated container, such as an insulated gas cylinder.

$$E_{in} = E_{out} = 0 \qquad\qquad m_{in} = m_{out} = 0$$

***Closed* systems or control mass:** exchanging energy (heat and work) but not matter with their environment. A greenhouse is an example of a closed system exchanging heat but not work with its environment. Another example is a piston cylinder in which heat and work can cross the boundary and volume may also change.

$$\Delta E \neq 0 \qquad\qquad m = constant$$

Whether a system exchanges heat, work or both is usually thought of as a property of its boundary, which can be

- *Adiabatic* boundary: not allowing heat exchange
- *Rigid* boundary: not allowing exchange of work

***Open* systems or control volume:** exchanging energy (heat and work) and matter with their environment. A boundary allowing matter exchange is called *permeable*. The ocean would be an example of an open system. Other examples are water heater, car radiator, turbine, nozzle.

$$\Delta E = E_{out} - E_{in} \neq 0 \qquad\qquad \Delta m = m_{out} - m_{in} \neq 0$$

In reality, a system can never be absolutely isolated from its environment, because there is always at least some slight coupling, even if only via minimal gravitational attraction. In analyzing an open system, the energy into the system is equal to the energy leaving the system.

Other types of system

Rigid system: A closed system that communicates with the surroundings by heat only.

Adiabatic system: A closed or open system that does not exchange energy with the surroundings by heat.

PROPERTIES OF A SYSTEM

Thermodynamic property

Any characteristic of a system is called a *property*. A measurable quantity that defines the condition of a system e.g. temperature T, pressure P, mass m, volume V, density ℓ

Intensive properties: These are properties that are independent of the size (mass) of a system, such as temperature, pressure, and density. They are not additive.

Extensive properties: These are properties that are dependant on size of the system such as mass, volume, and total energy U. They are additive. Extensive properties per unit mass are called specific properties, e.g. specific volume (v=V/m).

Note: Generally, uppercase letters are used to denote extensive properties (except mass m), and lower case letters are used for intensive properties (except pressure P, temperature T).

THERMODYNAMIC STATE

At a given *state*, all the properties of a system have fixed values. Thus, if the value of even one property changes, the state will change to different one.

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.

- Thermal equilibrium: when the temperature is the same throughout the entire System.
- Mechanical equilibrium: when there is no change in pressure at any point of the system. However, the pressure may vary within the system due to gravitational effects.
- Phase equilibrium: in a two phase system, when the mass of each phase reaches an equilibrium level.
- Chemical equilibrium: when the chemical composition of a system does not change with time, i.e., no chemical reactions occur.