

TERMS AND DEFINITIONS

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In this chapter the most important terms related to the subject of thermodynamics will be introduced and defined to simplify this subject for new students in the department of mechanical engineering.

What is thermodynamics?

This term is slightly misleading since linguistically it means the dynamic of heat which is not true. The subject of thermodynamics studies the conversion of all forms of energy from one to the other especially thermal energy and kinetic energy. Thermodynamics may be classified into two parts: classical thermodynamics and statistical thermodynamics.

The classical thermodynamics studies the properties and energy of the bulk substance.

The statistical thermodynamics studies the properties and energy of the molecules and atoms that form the substance.

Concentration will be devoted to classical thermodynamics since the subject is intended for engineering students in the B.Sc. level.

Let us start defining the terms that will be faced throughout this subject in the next lectures.

ENERGY

It is difficult to give an accurate definition for this term but a general definition may be introduced which “the ability to exert an effect”. There are different forms of energy such as, thermal energy, electrical energy, magnetic energy, light, sound, kinetic energy, potential energy.....etc. All these forms can be converted from one type to the other but the sum of all forms of energy in the universe is constant. Energy may be stored in the system or transferred from one system to another.

SYSTEM

A quantity of substance or a region in space identified for study and analysis.

BOUNDARIES

A real or imaginary surface encloses the system.

SURROUNDINGS

Everything outside the system boundaries.

There are two types of system.

1-THE CLOSED SYSTEM (CONTROL MASS SYSTEM)

The system where energy only can cross its boundaries as shown in fig (1).

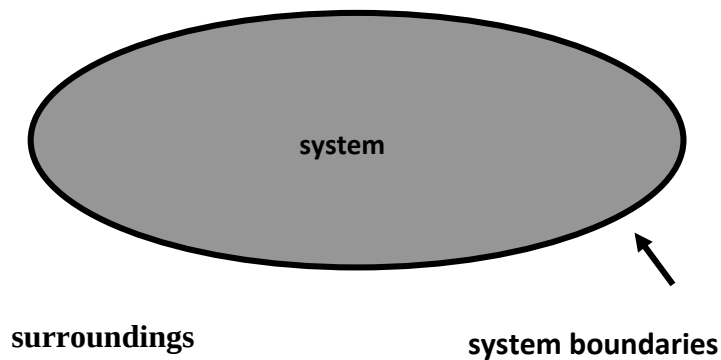


Fig (1) Representation of a Closed System

The cylinder arrangement of an internal combustion engine is considered as a closed system during the compression and expansion processes as shown in fig (2).

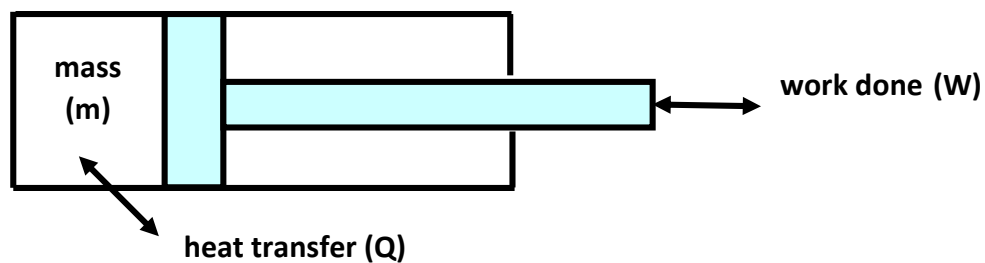


Fig (2) Cylinder Arrangement of an Internal Combustion Engine

2-THE OPEN SYSTEM (CONTROL VOLUME SYSTEM)

The system that mass and energy can cross its boundaries such as gas turbine, pump, pipe network,...etc. The surface enclosing the open system is known as the control surface. This system is represented in fig (3).

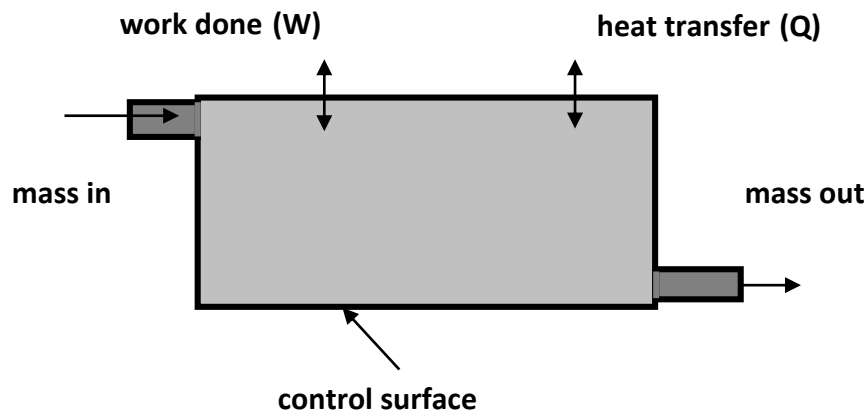


Fig (3) Representation of an Open System

STATE

The state of a system is the conditions of the system at a certain instant. The state of the system is described by certain bulk quantities known as system properties. The state of the system is represented as a point on the property diagram as shown in fig (4).



Fig (4) Representation of system state on property diagram

PROPERTY

It is the quantity that its value depends on the state of the system and independent on the path taken by the system to arrive at this state such as pressure, temperature, density, volume mass.....etc.

This book is concerned only with thermodynamic properties of system. The properties are classified into: INTENSIVE PROPERTIES and EXTENSIVE PROPERTIES.

INTENSIVE PROPERTY

The property that its value is constant and uniform throughout the system and independent of its mass such as pressure, temperature specific volume, density, ...etc.

EXTENSIVE PROPERTY

The property that its value depends on the system mass such as volume total internal energy etc. The extensive property per unit mass becomes intensive property such as specific volume, specific internal energy, ...etc

$$v = \frac{V}{m} \quad (1)$$

$$u = \frac{U}{m} \quad (2)$$

where,

V=total volume (m³), m=mass (kg), v=specific volume (m³/kg)

U=total internal energy (kJ), m=mass (kg), u=specific internal energy (kJ/kg)

The system properties may also be classified into DEPENDENT and INDEPENDENT.

DEPENDENT PROPERTY

It is the property that its value must change when the value of another property is changed such density and specific volume or the pressure and temperature during the change of phase process.

INDEPENDENT PROPERTY

It is the property that its value can be changed without changing the values of other properties such as pressure, temperature, specific internal energy etc.

INTERACTION

The change of the system state when the state of adjacent system or surroundings is changed. This interaction occurs through the common boundaries between the two systems or the system and its surroundings. When the possible interaction occurs then the two systems are in **communication** and when the interaction is impossible then the two systems are **isolated**.

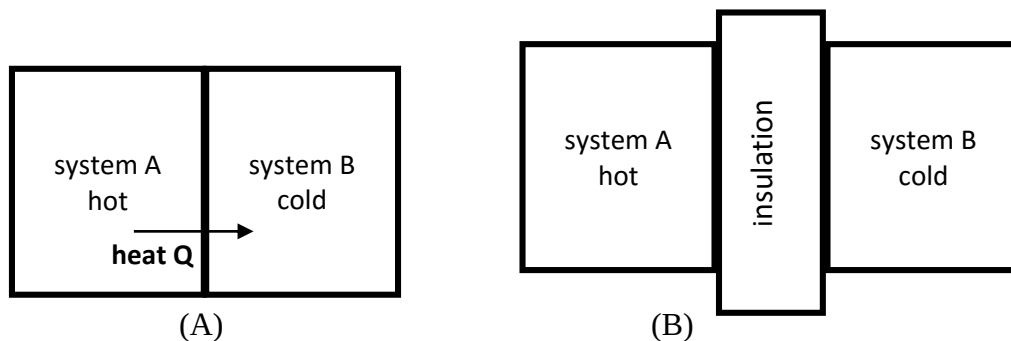


Fig (4) A-systems in communication, B-isolated systems

PROCESS

The change of state of system with or without interaction from an initial state to a final state passing through many intermediate states. These intermediate states traces the path of the process between the initial state and the final state. To describe any process completely the following information is required:

- a- system initial state,
- b- system final state,

- c- path of the process,
- d- type of interaction during the process.

Any process can be traced on property diagrams such as P-V diagram, T-S diagram.

Processes are classified as:

a-Reversible process: which is the process that during which the system and surroundings can be restored to their original state at any stage. This process is represented by a solid line on the property diagram as shown in fig (5A).

b-Irreversible process: which is the process that neither the system nor the surroundings or both can be restored to their original state. It is represented as a dotted line on the property diagram as shown in fig (5B). It must be stressed here that all real processes are irreversible.

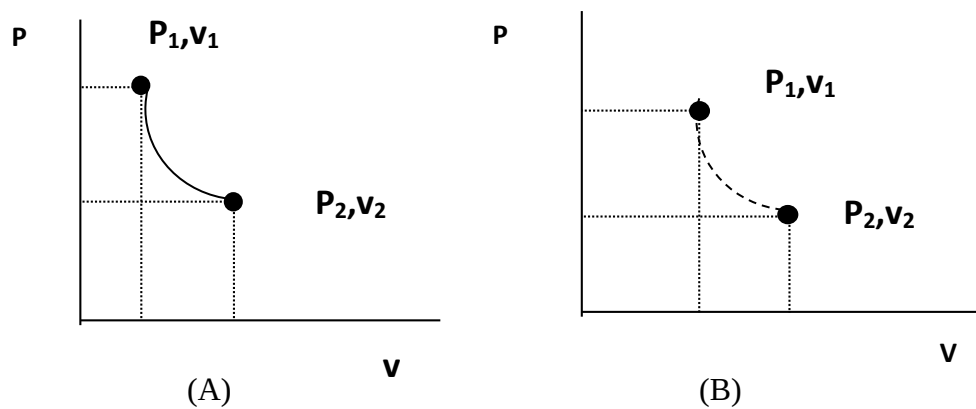


Fig (5) Representation of a Process on the Property Diagram

CYCLE

A series of processes that starts and ends at the same state and causes no net change in the state of the system as shown in fig (6). There are many thermodynamic cycles as will be seen in the coming lectures. If all processes forming the cycle are reversible then the cycle is reversible otherwise it is irreversible.

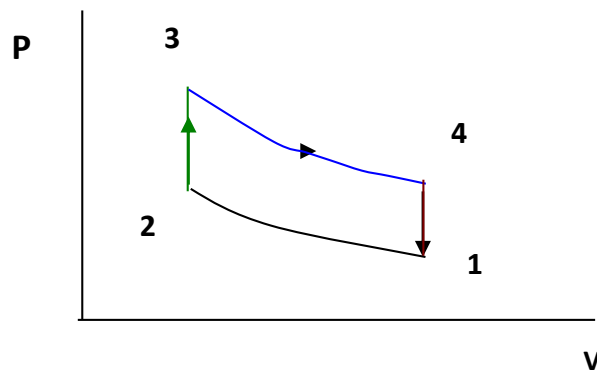


Fig (6) A Cycle on the P-V Diagram

EQUILIBRIUM

If two thermodynamic systems are free to interact in any possible way their states will change and eventually reach a particular state where the interaction between the two systems ceases. This state is known as the equilibrium state. The equilibrium state exists only on macroscopic scale. On microscopic scale the system is in state of constant fluctuations and is far from being at rest. There are four types of equilibrium depending on the nature of interaction.

1-Thermal equilibrium

2-Mechanical equilibrium

3-Chemical equilibrium

4-Diffusion equilibrium

If all types of equilibrium are satisfied then the system is in total equilibrium.

PRESSURE

It is the normal force exerted by the system on a unit area of its surroundings.

$$P = \frac{F_n}{A} \quad \text{where} \quad (3)$$

F_n =normal force (N)

A =area (m^2)

The units of pressure in SI units is Pascal (Pa) and its multiples (kPa) and (MPa)

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

There are two other units may be used for pressure which are bar and atmosphere (atm).

$$1 \text{ bar} = 10^5 \text{ Pa} = 0.1 \text{ MPa}$$

$$1 \text{ atm} = 101325 \text{ N/m}^2$$

There are many devices to measure the pressure such as: manometer, bourdon gauge, pitot tube.

The device used to measure the atmospheric pressure is known as the barometer.

The pressure measured by any device is known as the gauge pressure. The summation of the gauge pressure and the atmospheric pressure is known as the absolute pressure.

When the system pressure is less than the atmospheric pressure it is known as the vacuum pressure.

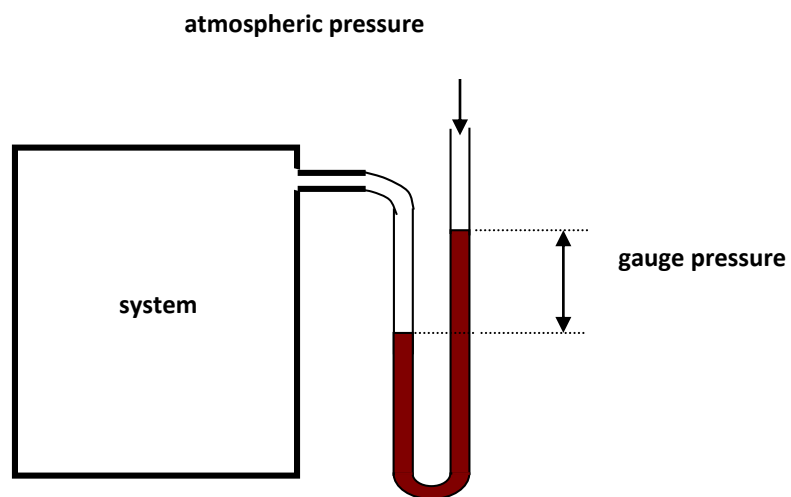


Fig (7) The Manometer

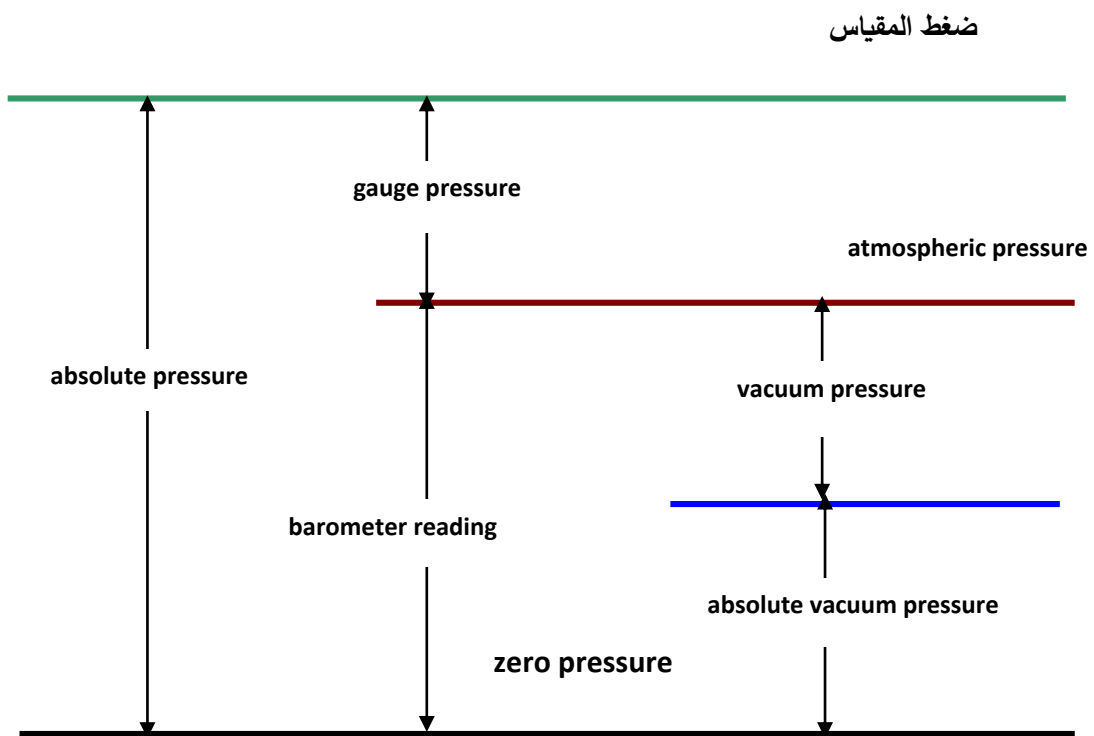


Fig (8) Pressure scale

TEMPERATURE

Although it is one of the basic properties of system but there is no definite definition for it. However the temperature is simply defined as the sense of hotness or coldness of a system.

The unit of temperature is either degree centigrade ($^{\circ}\text{C}$) in the Celsius or centigrade scale or degree Fahrenheit ($^{\circ}\text{F}$) in the Fahrenheit scale. In SI scale the ($^{\circ}\text{C}$) unit is used. The unit of absolute temperature (K).

$$1 \text{ K} = ^{\circ}\text{C} + 273.15$$

The absolute zero equals -273.15°C

There are two unique points on the centigrade scale:

1-Ice point temperature: it is the temperature of a mixture of ice and liquid water which is in equilibrium with saturated air at atmospheric pressure (101325 N/m^2).

2-Vapor point temperature: it is the temperature of a mixture of saturated liquid and saturated vapor in equilibrium at atmospheric pressure (101325 N/m^2).

The interval between these two points on the centigrade scale is divided into one hundred division and each division is known as degree temperature while in the Fahrenheit scale the interval is divided into 180 division.

To convert the temperature from one scale to another the following conversion equations are used.

$$^{\circ}\text{F} = 9/5 \times ^{\circ}\text{C} + 32$$

$$^{\circ}\text{C} = 5/9 \times [^{\circ}\text{F} - 32]$$

ZEROTH LAW OF THERMODYNAMICS

This law is stated as “when the temperatures of two systems equal the temperature of a third system then the temperatures of the two systems are equal”.

$$T_A = T_C \quad \text{and} \quad T_B = T_C$$

$$\text{Hence, } T_A = T_B$$

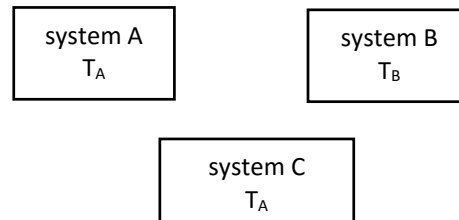


Fig (9) Three Systems