|| Jai Sri Gurudev||

Sri Adichunchanagiri Shikshana Trust®

SJB INSTITUTE OF TECHNOLOGY

(Affiliated to Visvesvaraya Technological University, Belagavi & Approved by AICTE, New Delhi.)

Accredited with NAAC 'A' grade

No. 67, BGS Health & Education City, Dr. Vishnuvardhan Road Kengeri, Bengaluru – 560 060

Department of Mechanical Engineering

Academic Year : **ODD SEM /2021-22**

SEMESTER : **3RD SEMESTER'A' SECTION**

SUBJECT : **BASIC THERMODYNAMICS**

BY

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ASSISTANT PROFESSOR

COLLEGE VISION & MISSION

College Vision

- To become a recognized technical education center with global perspective.

College Mission

- To provide learning opportunities that fosters students ethical values, intelligent
- development in science and technology and social responsibility so that they become
- sensible and contributing members of the society.

Department vision & Mission

Vision of the Department

To become a center of excellence and a platform in diversified fields for the aspirants in Mechanical Engineering.

Mission of the Department

- To impart comprehensive education in the field of mechanical engineering to produce highly accomplished graduates
- To endow high profile technical & soft skill trainings to foster professionalism and ethical values among students
- To inculcate innovative thinking among students through projects and research work

PROGRAM EDUCATIONAL OBJECTIVES

PEO1

- Progress their career as a **professional** in mechanical engineering and interdisciplinary fields.

PEO2

- Become successful **entrepreneur** with **social responsibilities** and **ethical values.**

PEO3

- Pursue **higher education** and involve in **research** of allied areas in mechanical engineering.

PROGRAM SPECIFIC OUTCOMES

PSO1

- Apply the Knowledge & Skill of Mechanical Engineering on Design, Manufacturing and Thermal platforms to address the real life problem of the society.

PSO2

- Design and implement new ides with the help of CAD/CAM and Industrial Automation tools.

PROGRAM OUTCOMES (PO'S)

PO1

Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2

Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3

Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4

Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5

Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6

The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PROGRAM OUTCOMES (PO'S)

PO7

Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8

Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9

Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10

Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11

Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12

Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

COURSE OUTCOMES:
AT THE END OF THE COURSE, THE STUDENT WILL BE ABLE TO:

CO'S	COURSE OUTCOMES	PO Mapped
CO1	Explain fundamentals of thermodynamics and evaluate energy interactions across the boundary of thermodynamic systems.	PO1
CO2	Apply 1st law of thermodynamics to closed and open systems and determine quantity of energy transfers and change in properties.	PO1, PO2
CO3	Evaluate the feasibility of cyclic and non-cyclic processes using 2nd law of thermodynamics. Apply the knowledge of entropy to solve numerical problems.	PO1, PO2
CO4	Interpret the behavior of pure substances and its application in practical problems. Apply the knowledge of reversibility and irreversibility to solve numerical problems.	PO1, PO2
CO5	Recognize differences between ideal and real gases and evaluate thermodynamic properties of ideal and real gas mixtures using various relations.	PO1, PO2

MODULE 1

FUNDAMENTAL CONCEPTS & DEFINITIONS

Thermodynamic definition and scope, Microscopic and Macroscopic approaches. Some practical applications of engineering thermodynamic Systems, Characteristics of system boundary and control surface, examples. Thermodynamic properties; definition and units, intensive, extensive properties, specific properties, pressure, specific volume, Thermodynamic state, state point, state diagram, path and process, quasi-static process, cyclic and non-cyclic; processes; Thermodynamic equilibrium; definition, mechanical equilibrium; diathermic wall, thermal equilibrium, chemical equilibrium, Zeroth law of thermodynamics, Temperature; concepts, scales, international fixed points and measurement of temperature. Constant volume gas thermometer, constant pressure gas thermometer, mercury in glass thermometer.

THERMODYNAMIC DEFINITION AND SCOPE

Thermodynamics is a branch of science that deals with energy in all its forms and the laws governing the transformation of energy from one form to another. The form of energy are mechanical, thermal or heat, chemical, electrical etc.

Thermodynamics deals with the behavior of gases and vapours i.e., the working substances when subjected to variation of temperature and pressure and the relationship between heat energy and mechanical energy commonly referred to as work.

Energy transformation takes place when a substance undergoes a change from one condition to another in a process. The processes are heating or cooling and expansion or compression in the cylinder or passages with or without production or supply of mechanical work.

Different Branches of Thermodynamics

Thermodynamics is classified into the following four branches:

Classical Thermodynamics

In classical thermodynamics, the behaviour of matter is analyzed with a macroscopic approach. Units such as temperature and pressure are taken into consideration, which helps the individuals calculate other properties and predict the characteristics of the matter undergoing the process.

Statistical Thermodynamics

In statistical thermodynamics, every molecule is under the spotlight, i.e. the properties of every molecule and how they interact are taken into consideration to characterize the behaviour of a group of molecules.

Chemical Thermodynamics

Chemical thermodynamics is the study of how work and heat relate to each other in chemical reactions and changes of states.

Equilibrium Thermodynamics

Equilibrium thermodynamics is the study of transformations of energy and matter as they approach the state of equilibrium.

Macroscopic and Microscopic aspects

The description of a system or matter using a few of its measurable bulk properties constitutes a point of view called Macroscopic. The measurable properties are pressure, volume, temperature etc.

The state or condition of the system is completely described by means of above large scale characteristics or properties of the system. Such properties are called macroscopic properties and these describe the system from macroscopic point of view.

The study of the behavior of the gas described by summing up the behavior of each molecule is microscopic or statistical thermodynamics.

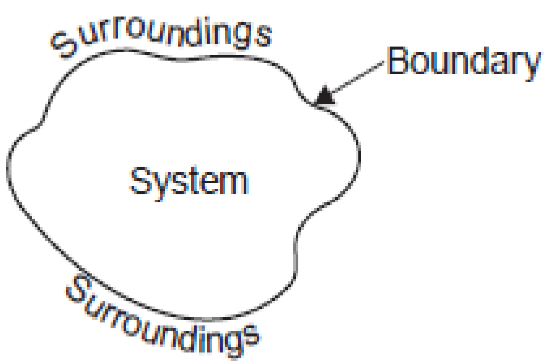
Sl no	MACROSCOPIC APPROACHES	MICROSCOPIC APPROACHES
1	In this approach a certain quantity of matter is considered without taking in to account of events occurring at molecular level .In other words this approach to the thermodynamics is concerned with gross or over all behavior. This is known as classical thermodynamics.	The approach considered that the system is made up of a very large number of discrete particles known as molecules. These molecules have different velocities and energies. Thevalues of these energies are constantly changing with time. This is known as statistical thermodynamics.
2	The analysis of macroscopic system requires simple mathematical formula.	The behavior of the system is found by using statistical methods as the number of molecules very large. So advanced statistical and mathematical methods are needed to explain the changes in the system.
3	The values of the properties of the system are their average values.	The properties like velocities, momentum, impulse, kinetic energy etc... Which describe the molecule cannot be easily measured by instruments.
4	In order to describe a system only a few properties are needed.	Large numbers of variables are needed to describe a system. So the approach is complicated.

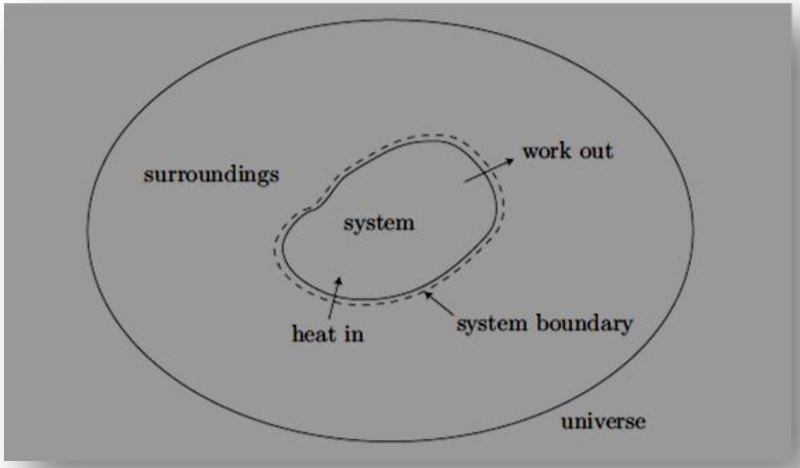
SOME PRACTICAL APPLICATIONS

- simple steam power plant,
- fuel cells,
- vapor-compression refrigeration cycle,
- air separation plant,
- the gas turbine, and
- the chemical rocket engine.

SYSTEM BOUNDARY SURROUNDING AND UNIVERSE

- **Thermodynamic system**: a quantity of fixed mass under investigation,
- **Surroundings:** everything external to the system,
- **System boundary:** interface separating system and surroundings, and
- **Universe:** combination of system and surroundings.
- **Control Volume:** fixed volume over which mass can pass in and out of its boundary. The control volume is bounded by the
- **Control Surface:** boundary of the control volume.



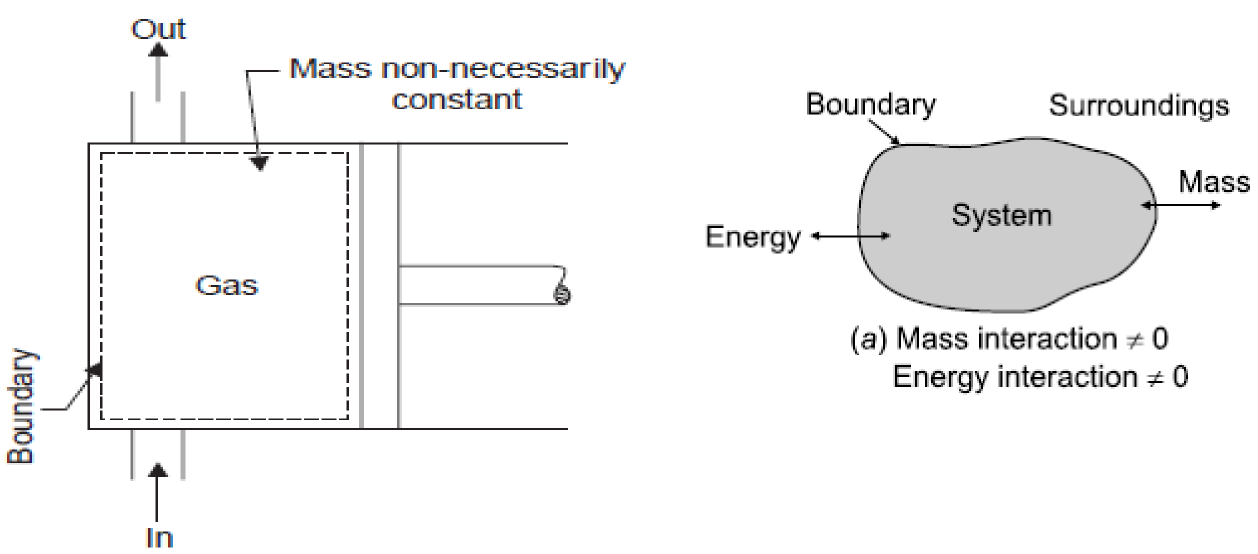


THERMODYNAMIC SYSTEMS

- Closed System (Control Mass)
- Open System (Control Volume)
- Isolated System
- Adiabatic System
- Homogeneous System
- Heterogeneous System

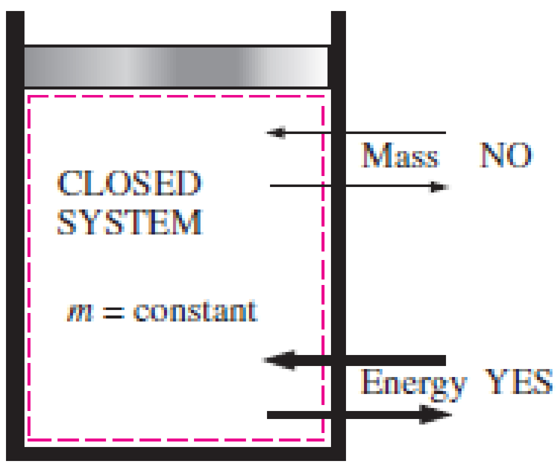
Open System

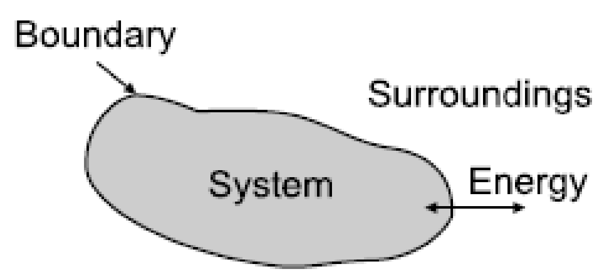
An open system is one in which matter flows into or out of the system. Most of the engineering systems are open. The boundaries of a control volume are called a **control surface.**



Closed System

A **closed system** (also known as a **control mass**) consists of a fixed amount of mass, and nomass can cross its boundary. That is, no mass can enter or leave a closed system, as shown in Fig. But energy, in the form of heat or work, cancross the boundary; and the volume of a closed system does not have to befixed

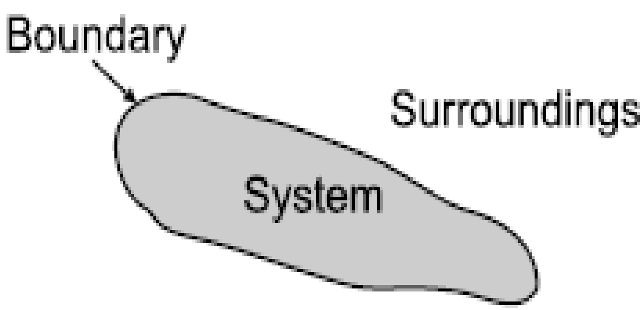




(*b*) Mass interaction = 0
Energy interaction ≠ 0

ISOLATED SYSTEM

An isolated system is that system which exchanges neither energy nor matter with any other system or with environment.



(*c*) Mass interaction = 0
Energy interaction = 0

Adiabatic System

An adiabatic system is one which is thermally insulated from its surroundings. It can, however, exchange work with its surroundings. If it does not, it becomes an isolated system.

Phase

A phase is a quantity of matter which is homogeneous throughout in chemical composition and physical structure.

Homogeneous System

A system which consists of a single phase is termed as homogeneous system.

Examples: Mixture of air and water vapour.

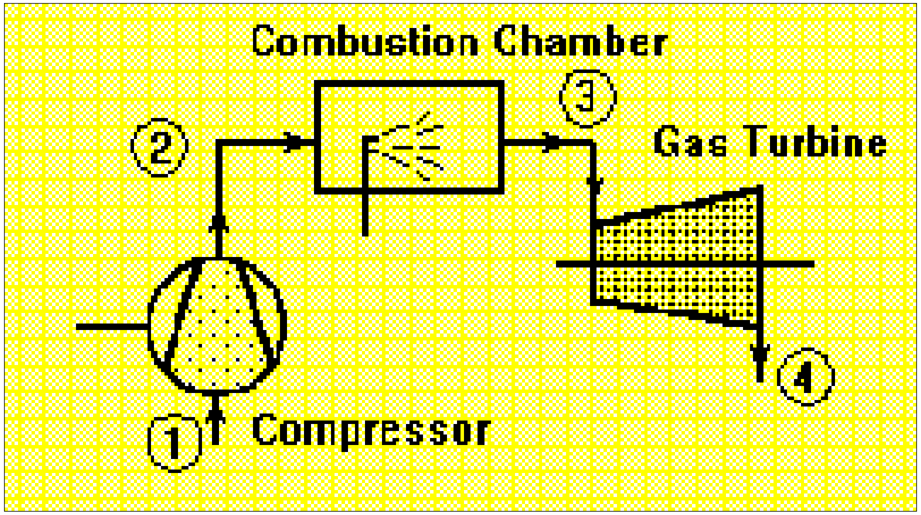
Heterogeneous System

A system which consists of two or more phases is called a heterogeneous system.

Examples: Water plus steam, ice plus water and water plus oil.

Control Volume and Control Surface

In thermodynamic analysis of an open system such as air compressor, gas turbine in which there is a flow of mass into and out of the system, attention is focused on a certain volume in space surrounding the compressor known as control volume, bounded by a surface called the control surface. Matter as well as energy can cross the control surface.



Homogeneous and Heterogeneous system

A quantity of matter homogeneous throughout in chemical composition and physical structure is called a phase. Every substance can exist in any one of the three phases viz. Solid, Liquid or gas.

A system consisting of a single phase is called a homogeneous system while a system consisting of more than one phase is known as a heterogeneous system.

INTENSIVE, EXTENSIVE PROPERTIES,

- **Extensive Property:** a property that depends on the mass (or the extent) of the system, example extensive properties include mass, total volume, total energy, and
- **Intensive Property:** a property that is independent of the mass of the system. Example intensive properties include temperature and pressure.

THERMODYNAMIC PROPERTIES

The variables which determine state or exact condition of a substance or system is called as its properties. The various properties of thermodynamic system are pressure, temperature, specific volume, internal energy, enthalpy, entropy, etc.

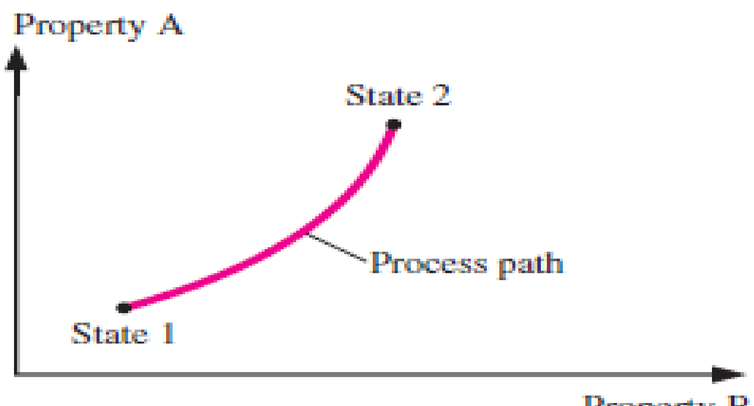
THERMODYNAMIC STATE, PROCESS,

STATE

State is the condition of the system at an instant of time as described or measured by its properties. Or each unique condition of a system is called a **state.**

PROCESS

Whenever one or more of the properties of a system change, a change in the state of the system occurs. The path of the succession of states through which t he system passes is called the**thermodynamic process**.

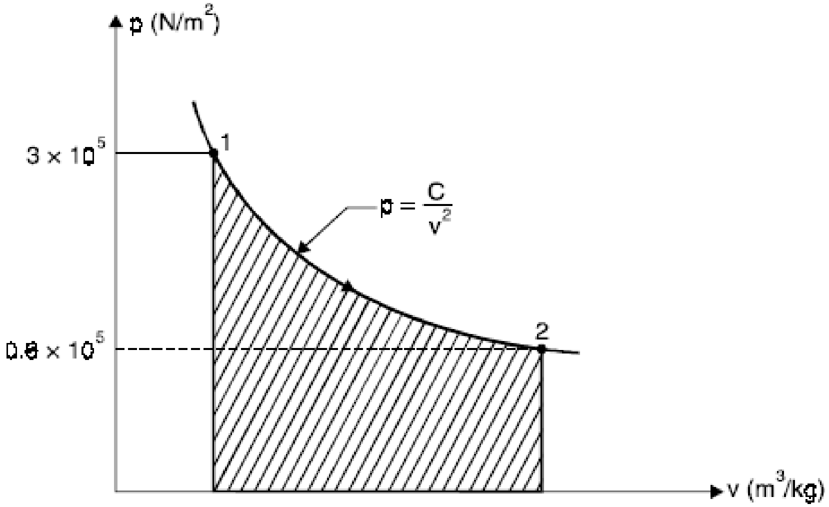


POINT FUNCTION

When two properties can be located on the thermodynamic diagram, then those properties are called point function. For example pressure, temperature, volume are the point function since these can be located on the thermodynamic diagram as shown in fig and their change can be written as difference between their end states.

Change in volume dv= V2-V1

Change in pressure dp=P2-P1



PATH FUNCTION

There are certain quantities which cannot be located on the thermodynamic diagram by point and also whose change cannot be written as the difference between their end states. The change in their values given by the area under the thermodynamic diagram.Such a quantities are called path function. **For example heat and work**

Change in heat $$\int_1^2 \delta Q = Q_{1-2} \text{ or } {}_1Q_2 \text{ (or } Q)$$

Work done $$\int_1^2 \delta W = W_{1-2} \text{ or } {}_1W_2 \text{ (or } W),$$

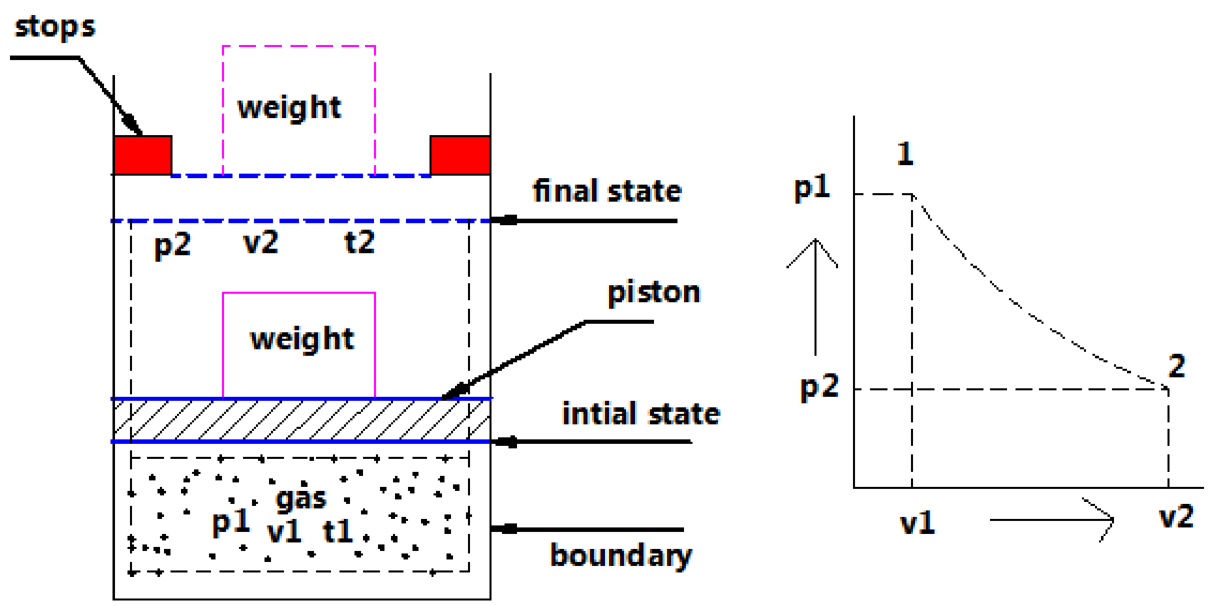
The following terms are used for thermodynamic transformations

- isobaric - the pressure p of the system is constant;
- monobaric - the external pressure p0 is constant;
- isochoric - the volume V of the system is constant;
- isotherm - the temperature T of the system is constant;
- monotherm - the outside temperature T0 is constant;
- adiabatic - the system evolves without heat exchange with its surroundings

QUASI-STATIC PROCESS,

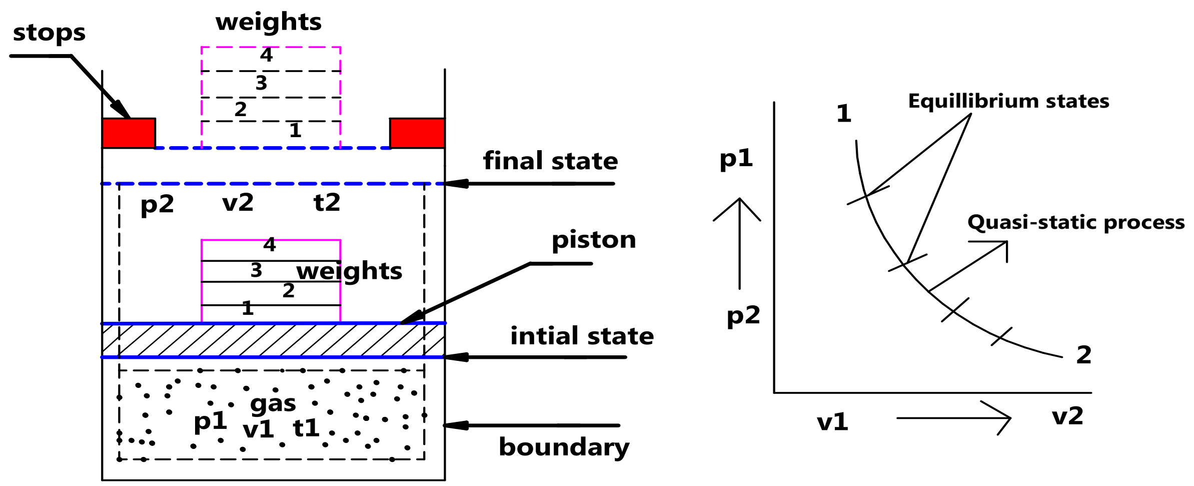
A quasi-static process is also called a reversible process. This process is a succession of equilibrium states and infinite slowness is its characteristic feature.

Let considera system of gas contained in a cylinder as shown in fig. the system initially is in equilibrium state, represented by the p1, v1, and t1. The weights on the piston just balanced the upward force exerted by the gas. If is removed, there will be an unbalanced force between the system and the surrounding, and under gas pressure, the piston will move up till it hits the stops



Transition b/w two equilibrium states by an unblanced forces & pv diagram

The system again comes to an equilibrium state, being described by the properties p2, v2, t2.but the intermediate states passed through by the system are nonequilibrium states which cannot be described by thermodynamics coordinates. Fig shows position 1 and 2 as initial and final equilibrium states joined by a dotted line, which got no meaning otherwise.



Infinitly slow Transition b/w two equilibrium states & pv diagram

Now if the single weight on the piston is made up of many very small pieces of weight as shown in fig and these weights removed one by one very slowly from top of the

piston, at any instant of the upward travel of the piston, if the gas system is isolated, the departure of the state of the system from the thermodynamics equilibrium state will be infinitesimally small. So every state passed through by the system will be an equilibrium state. Such a process, which is but a locus of all the equilibrium state, is known as Quasi-static Processes. It is also called as reversible process.

examples of nearly reversible processes are :

(*i*) Frictionless relative motion.

(*ii*) Expansion and compression of spring.

(*iii*) Frictionless adiabatic expansion or compression of fluid.

(*iv*) Polytropic expansion or compression of fluid.

(*v*) Isothermal expansion or compression.

(*vi*) Electrolysis.

examples of nearly irreversible process are.

(*i*) Relative motion with friction (*ii*) Combustion

(*iii*) Diffusion (*iv*) Free expansion

(*v*) Throttling (*vi*) Electricity flow through a resistance

(*vii*) Heat transfer (*viii*) Plastic deformation

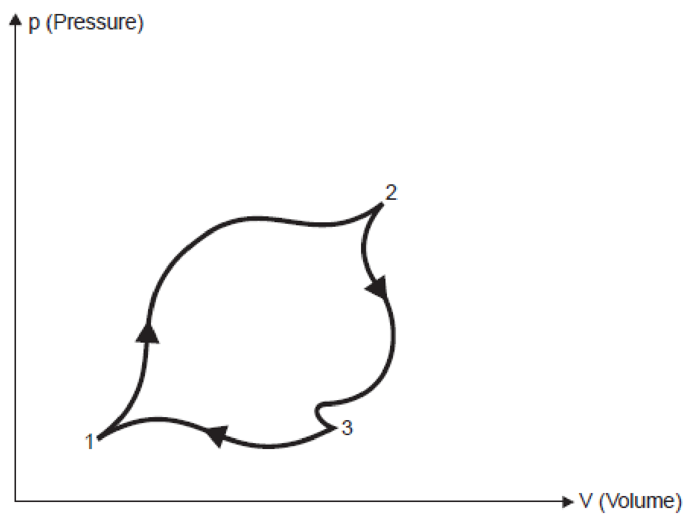
CYCLE

Any process or series of processes whose end states are identical is termed a **cycle.**

Or

If, at the end of the process, the properties have returned to their original values, the system has undergone a **cyclic process** or a **cycle**.

The **path** refers to the series of state changes through which the system passes during a process.



THERMODYNAMIC EQUILIBRIUM

The word equilibrium implies a state of balance. In an equilibrium state, there are no unbalanced potentials within the system or driving forces. Thus, a system in equilibrium experiences no changes when it is isolated from its surroundings.

Thermal Equilibrium:

If the temperature is the same throughout the entire system .i.e the system involves no temperature differential which is the driving force or heat flow then we say system is in thermal equilibrium.

Mechanical equilibrium:

It is related to pressure, velocity. A system is in mechanical equilibrium if there is no change in pressure, velocity, specific volume at any point of the system with respect to time. However the pressure may vary within the system with elevation as well as resultant of gravitational effects. However there should not be any imbalance of forces. Then we say the system is in mechanical equilibrium

Phase equilibrium:

If a system involves two phases it is in phase equilibrium when the mass of each phase reaches equilibrium level and stays there.

Chemical equilibrium:

If the systems chemical composition does not change with time, i.e., no chemical reaction occur then we say the system is in chemical equilibrium. Thus if all thermal, mechanical, phase and chemical equilibrium exist for a system then we say the system exist in thermodynamic equilibrium

Diathermic wall:

A wall which is impermeable to the flow of heat is an adiabatic wall, where as a wall which permits the flow of heat is a diathermic wall. Thus heat flow takes place through this wall.

TEMPERATURE

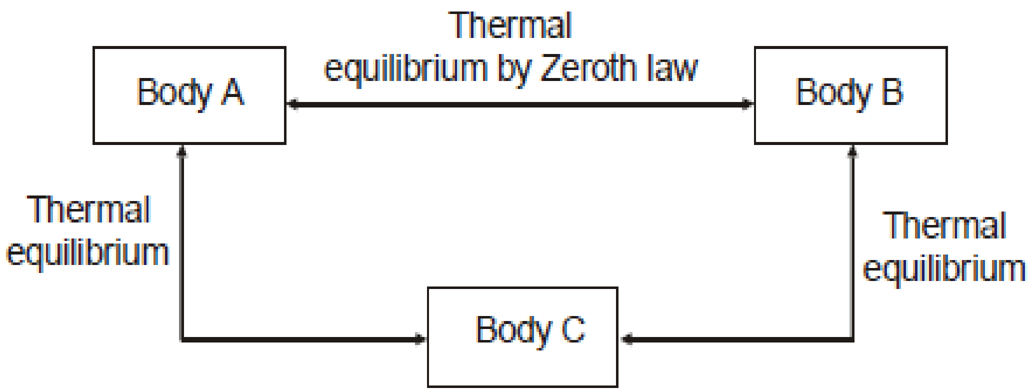
The temperature is a thermal state of a body which distinguishes a hot body from a cold body.

Instruments for measuring ordinary temperatures are known as **thermometers** and those for measuring high temperatures are known as **pyrometers.**

ZEROTH LAW OF THERMODYNAMICS,

Zeroth law of thermodynamics' states that if two systems are each equal in temperature to a third, they are equal in temperature to each other.

Zeroth law of thermodynamics states that if the bodies A and B are in thermal equilibrium with a third body C separately then the two bodies A and B shall also be in thermal equilibrium with each other.



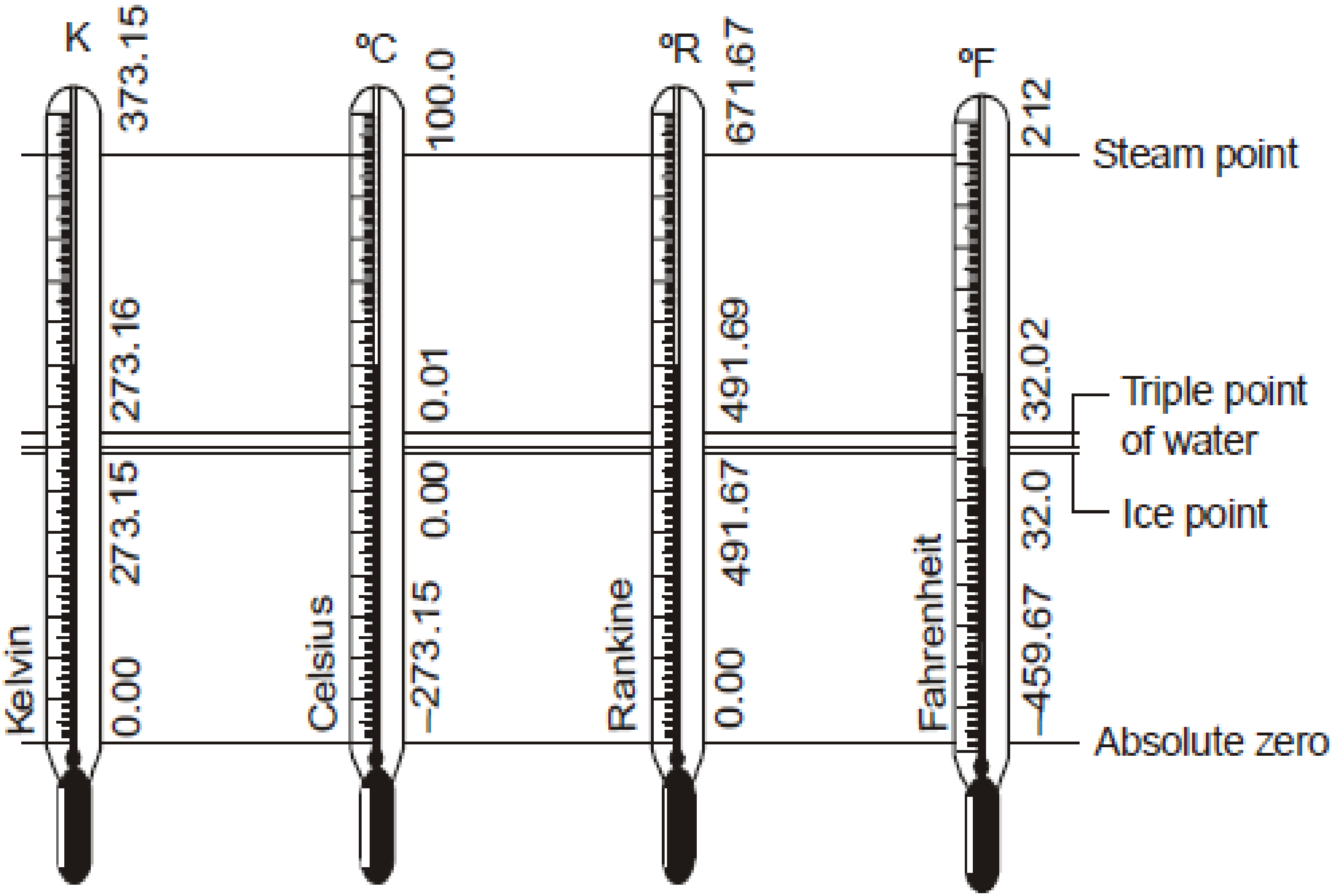
TEMPERATURE SCALES

Celsius Scale or Centigrade Scale- Anders Celsius gave this Celsius or Centigrade scale using ice point of 0°C as the lower fixed point and steam point of 100ºC as upper fixed point for developing the scale.

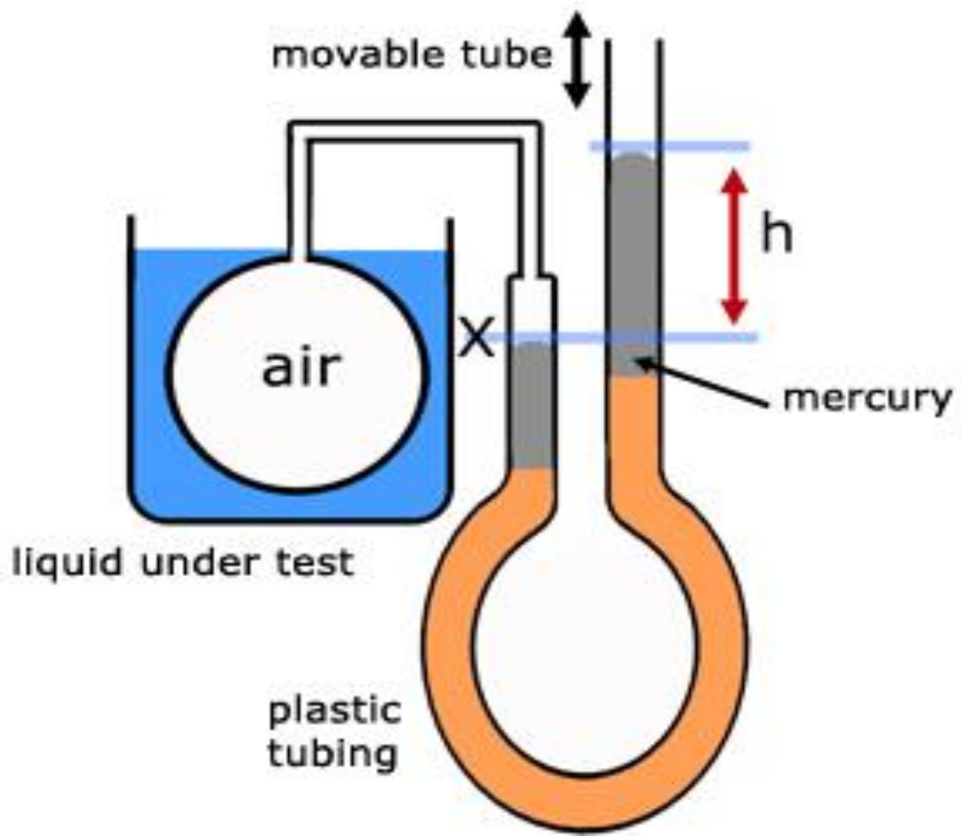
Fahrenheit Scale- Fahrenheit gave another temperature scale known as Fahrenheit scale and has the lower fixed point as 32 F and the upper fixed point as 212 F.

Rankinescale- Rankine scale was developed by William John MacQuornRankine, a Scottish engineer. It is denoted by letter *R*. It is related to Fahrenheit scale as given below.

Kelvin Scale- Kelvin scale proposed by Lord Kelvin is very commonly used in thermodynamic analysis. It also defines the absolute zero temperature. Zero degree Kelvin or absolute zero temperature is taken as –273.15ºC. It is denoted by letter K.


K
373.15
273.16
273.15
0.00
Kelvin
°C
100.0
0.01
0.00
–273.15
Celsius
°R
671.67
491.69
491.67
0.00
Rankine
°F
212
32.02
32.0
–459.67
Fahrenheit
Steam point
Triple point of water
Ice point
Absolute zero

CONSTANT VOLUME GAS THERMOMETER,



In its original state the glass bulb is full of air and the mercury levels are the same. A mark(X) is made against the glass to record this.

When the bulb is placed in a hot liquid for a temperature reading, the air in the bulb expands, pushing the mercury down on the left and up on the right.

To get the air in the flask back to its original volume, the movable tube is lowered until the mercury is at the level previously marked.

There is now a level difference (head) $\boldsymbol{h}$ between the two tubes. This is a measure of the pressure of the gas without taking account of atmospheric pressure $\boldsymbol{p}_A$. So accounting for atmospheric pressure, the pressure $\boldsymbol{p}_\theta$ of the gas at temperature θ is:

$$p_\theta = p_A + h$$

It follows that the temperature of the gas, **θ** is given by:

$$\theta = \frac{p_\theta - p_0}{p_{100} - p_0}$$

where $\boldsymbol{p}_0$ and $\boldsymbol{p}_{100}$ are pressures at 0^oC & 100^oCrespectively.