SRIMAAN

TNMAWS

MUNICIPAL ADMINISTRATION & WATER SUPPLY DEPARTMENT-(MAWS)

Assistant Engineer (MECHANICAL)-(DEGREE)

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TN-MAWS - MECHANICAL ENGINEERING

(DEGREE STANDARD)

MUNICIPAL ADMINISTRATION & WATER SUPPLY DEPARTMENT

UNIT-IV-THERMAL ENGINEERING AND THERMODYNAMICS

Basic concepts, Zeroth, First and Second laws of thermodynamics

Thermodynamics is the study of the patterns of energy change. Most of this course will be concerned with understanding the patterns of energy change.

More specifically, thermodynamics deals with

(a) Energy conversion and

(b) The direction of change.

Basis of thermodynamics is experimental observation. In that sense it is an empirical science. The principles of thermodynamics are summarized in the form of four laws known as zeroth, first, second, and the third laws of thermodynamics.

The **zeroth law of thermodynamics** deals with thermal equilibrium and provides a means of measuring temperature.

The **first law of thermodynamics** deals with the conservation of energy and introduces the concept of internal energy.

The **second law of thermodynamics** dictates the limits on the conversion of heat into work and provides the yard stick to measure the performance of various processes. It also tells whether a particular process is feasible or not and specifies the direction in which a process will proceed. As a consequence it also introduces the concept of entropy.

The **third law defines** the absolute zero of entropy.

Macroscopic and Microscopic Approaches:

Microscopic approach uses the statistical considerations and probability theory, where we dealwith "average" for all particles under consideration. This is the approach used in the disciplines known as kinetic theory and statistical mechanics.

In the macroscopic point of view, of classical thermodynamics, one is concerned with the time-averaged influence of many molecules that can be perceived by the senses and measured by the instruments.The pressure exerted by a gas is an example of this. It results from the change in momentum of the molecules, as they collide with the wall. Here we are not concerned with the actions of individual molecules but with the time-averaged force on a given area that can be measured by a pressure gage.

From the macroscopic point of view, we are always concerned with volumes that are very large compared to molecular dimensions, and therefore a system (to be defined next) contains many molecules, and this is called continuum. The concept of continuum loses validity when the mean free path of molecules approaches the order of typical system dimensions.

System:

We introduce boundaries in our study called the **system** and **surroundings**.

The boundaries are set up in a way most conducive to understanding the energetics of what we're studying. Defining the system and surroundings is arbitrary, but it becomes important when we consider the exchange of energy between the system and surroundings.

Two types of exchange can occur between system and surroundings: (1) energy exchange (heat, work, friction, radiation, etc.) and (2) matter exchange (movement of molecules across the boundary of the system and surroundings). Based on the types of exchange which take place or don't take place, we will define three types of systems:

- **isolated systems:** no exchange of matter or energy
- **closed systems:** no exchange of matter but some exchange of energy
- **open systems:** exchange of both matter and energy

Control Volume

- Control volume is defined as a volume which encloses the matter and the device inside a control surface.
- Everything external to the control volume is the surroundings with the separation given by the control surface.
- The surface may be open or closed to mass flows and it may have flows from energy in terms of heat transfer and work across it.
- The boundaries may be moveable or stationary.

- In the case of a control surface that is closed to the mass flow, so that no mass can enter or escape the control volume, it is called a **control mass** containing same amount of matter at all times.

Property

- In thermodynamics a property is any characteristic of a system that is associated with the energy and can be quantitatively evaluated.
- The property of a system should have a definite value when the system is in a particular state.
- Thermodynamic property is a point function.
- Properties like volume of a system that depend on the mass of a system are called extensive properties.
- Properties like pressure or temperature which do not depend on the system mass are called intensive properties.
- The ratio of extensive property to the mass of the system are called specific properties and therefore become intensive properties.
- Substance can be found in three states of physical aggregation namely, solid, liquid and vapor which are called its phases.
- If the system consists of mixture of different phases, the phases are separated from each other by phase boundary.
- The thermodynamic properties change abruptly at the phase boundary, even though the intensive properties like temperature and pressure are identical.

Equilibrium:

- When the property of a system is defined, it is understood that the system is in equilibrium.
- If a system is in thermal equilibrium, the temperature will be same throughout the system.
- If a system is in mechanical equilibrium, there is no tendency for the pressure to change. In a single phase system, if the concentration is uniform and there is no tendency for mass transfer or diffusion, the system is said to be in chemical equilibrium.
- A system which is simultaneously in thermal, mechanical, and chemical equilibrium is said to be in thermal equilibrium.

PROCESS

A process is path followed by a system in reaching a given final state of equilibrium state starting from a specified initial state. An actual process occurs only when the equilibrium state does not exist.An ideal process can be defined in which the deviation from thermodynamic equilibrium is

infinitesimal.All the states the system passes through during a quasi-equilibrium process may be considered equilibrium states.

For non-equilibrium processes, we are limited to a description of the system before the process occurs and after the equilibrium is restored.Several processes are described by the fact that one property remains constant.The prefix iso- is used to describe such processes.

A process is said to be reversible if both the system and its surroundings can be restored to their respective initial states by reversing the direction of the process.

- **Reversible**: if the process happens slow enough to be reversed.
- **Irreversible**: if the process cannot be reversed (like most processes).
- **Isobaric:** process done at constant pressure
- **Isochoric:** process done at constant volume
- **Isothermal:** process done at constant temperature
- **Adiabatic:** process where q=0
- **Cyclic:** process where initial state = final state

Internal Energy

- The molecule as a whole can move in x, y and z directions with respective components of velocities and hence possesses kinetic energy.
- There can be rotation of molecule about its center of mass and than the kinetic energy associated with rotation is called rotational energy.
- In addition the bond length undergoes change and the energy associated with it is called vibrational energy.
- The electron move around the nucleus and they possess a certain energy that is called electron energy.
- The microscopic modes of energy are due to the internal structure of the matter and hence sum of all microscopic modes of energy is called the internal energy.

Bulk kinetic energy (KE) and potential energy (PE) are considered separately and the other energy of control mass as a single property (U).

The total energy possessed by the body is given by:

$$E = KE + PE + U$$

Work

Whenever a system interacts with its surroundings, it can exchange energy in two ways- work and heat. In mechanics, work is defined as the product of the force and the displacement in the direction of the force.

Work done when a spring is compressed or extended: According to Hooke's law

$$\text{Spring force} = - k (x - x_0)$$

Where k is the spring constant, x_0 is the equilibrium position, and x is the final position. The negative sign shows that the direction of the spring force is opposite the direction of the displacement from x_0. The external force is equal in magnitude but opposite in sign to the spring force, so

$$\text{External force (force of your hands)} = k (x - x_0).$$

Now, we want to calculate the work done when we stretch the spring from position 1 to position 2.

$$W = F\,dx = k (x - x_0)\, d(x-x_0) = 1/2\, k\, [(x_2-x_0)^2 - (x_1-x_0)^2]$$

Work done when a volume is increased or decreased

Consider a gas in a container with a movable piston on top. If the gas expands, the piston moves out and work is done by the system on the surroundings.

Alternatively, if the gas inside contracts, the piston moves in and work is done by the surroundings on the system. Why would the gas inside contract or expand?

It would if the external pressure, P_{ex}, and the internal pressure, P_{in}, were different. To calculate the work done in moving the piston, we know that the force = pressure times area and then work equals pressure times area times distance or work equals pressure times the change in volume. So, W = the integral of (P_{ex}) dV.

The differential work done (dW) associated with a differential displacement (dl) is given by

$$dW = F\, dl$$

For a piston cylinder assembly,

$$dW = F\,dl = PA\,(dl) = P\,dV$$

If the gas is allowed to expand reversibly from the initial pressure P to final pressure P, then the work done is given by

$$W = \int p\,dV$$

- The integral represents the area under the curve on a pressure versus volume diagram. Therefore the work depends on the path followed and work is a path function and hence not a property of the system.
- The above expression does not represent work in the case of an irreversible process.
- The thermodynamic definition of work is " Work is said to be done by a system on the surrounding if the sole effect external to the system could be reduced to the raising of a mass through a distance".

Heat:

Heat like work, is a form of energy. The energy transfer between a system and its surroundings is called heat if it occurs by virtue of the temperature difference across the boundary.The two modes of energy transfer – work and heat- depend on the choice of the system. Heat energy moves from a hotter body to a colder body upon contact of the two bodies. If two bodies at different temperatures are allowed to remain in contact, the system of two bodies will eventually reach a thermal equilibrium (they will have the same temperature).A body never contains heat. Rather heat is a transient phenomenon and can be identified as it crosses the boundary.

The State Postulate:

The state of the system is described by its properties.Once a sufficient number of properties are specified, the rest of the properties assume some values automatically.The number of properties required to fix a state of a system is given by the **state postulate**:

The state of a simple compressible system is completely specified by two independent, intensive properties. The system is calleda **simple compressible system** in the absence of electrical, magnetic, gravitational, motion, and surface tension effects.

The state postulate requires that the two properties specified be independent to fix the state.Two properties are independent if one property can be varied while the other one is held constant. Temperature and specific volume, for example, are always independent properties, and together they can fix the state of a simple compressible system.Thus, temperature and pressure are not

sufficient to fix the state of a two-phase system.Otherwise an additional property needs to be specified for each effect that is significant.An additional property needs to be specified for each other effect that is significant.

Zeroth Law of Thermodynamics

We cannot assign numerical values to temperatures based on our sensations alone. Furthermore, our senses may be misleading. Several properties of material changes with temperature in a repeatable and predictable way, and this forms the basis of accurate temperature measurement.The commonly used mercury-in-glass thermometer for example, is based on the expansion of mercury with temperature.Temperature is also measured by using several other temperature dependant properties.Two bodies (eg. Two copper blocks) in contact attain thermal equilibrium when the heat transfer between them stops.

The equality of temperature is the only requirement for thermal equilibrium.

The **Zeroth Law of Thermodynamics**

If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.This obvious fact cannot be concluded from the other laws of thermodynamics, and it serves as a basis of temperature measurement.By replacing the third body with a thermometer, the zeroth law can be restated *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.* The zeroth law was first formulated and labeled by R.H. Fowler in 1931.

Temperature Scales

All temperature scales are based on some easily reproducible states such as the freezing and boiling point of water, which are also called the ice-point and the steam-point respectively. A mixture of ice and water that is in equilibrium with air saturated with water vapour at 1atm pressure, is said to be at the ice-point, and a mixture of liquid water and water vapour (with no air) in equilibrium at 1atm is said to be at the steam-point.Celsius and Fahrenheit scales are based on these two points (although the value assigned to these two values are different) and are referred as two-point scales. In thermodynamics, it is very desirable to have a temperature scale that is independent of the properties of the substance or substances.

Such a temperature scale is called a **thermodynamic temperature scale**.(Kelvin in SI)

Ideal gas temperature scale

The temperatures on this scale are measured using a constant volume thermometer.Based on the principle that at low pressure, the temperature of the gas is proportional to its pressure at constant volume. The relationship between the temperature and pressure of the gas in the vessel can be expressed as

$$T = a + b.P$$

Where the values of the constants *a* and*b* for a gas thermometer are determined experimentally.

Once *a* and*b* are known, the temperature of a medium can be calculated from the relation above by immersing the rigid vessel of the gas thermometer into the medium and measuring the gas pressure.Ideal gas temperature scale can be developed by measuring the pressures of the gas in the vessel at two reproducible points (such as the ice and steam points) and assigning suitable values to temperatures those two points. Considering that only one straight line passes through two fixed points on a plane, these two measurements are sufficient to determine the constants *a* and*b* in the above equation.

If the ice and the steam points are assigned the values 0 and 100 respectively, then the gas temperature scale will be identical to the Celsius scale. In this case, the value of the constant *a* (that corresponds to an absolute pressure of zero) is determined to be -273.15^0C when extrapolated.

The equation reduces to T = bP, and thus we need to specify the temperature at only one point to define an absolute gas temperature scale. Absolute gas temperature is identical to thermodynamic temperature in the temperature range in which the gas thermometer can be used.We can view that thermodynamic temperature scale at this point as an absolute gas temperature scale that utilizes an ideal gas that always acts as a low-pressure gas regardless of the temperature. At the Tenth international conference on weights and measures in 1954, the Celsius scale has been redefined in terms of a single fixed point and the absolute temperature scale.The triple point occurs at a fixed temperature and pressure for a specified substance.

The selected single point is the **triple point** of water (the state in which all three phases of water coexist in equilibrium), which is assigned the value 0.01 C. As before the boiling point of water at 1 atm. Pressure is 100.0 C. Thus the new Celsius scale is essentially the same as the old one.

On the Kelvin scale, the size of Kelvin unit is defined as " the fraction of 1/273.16 of the thermodynamic temperature of the triple point of water, which is assigned a value of 273.16K". The ice point on Celsius and Kelvin are respectively 0 and 273.15 K.

Thermodynamic system and processes

A system is defined as a quantity of matter or a region in space chosen for study. The mass or region outside the system is called the surroundings. The real or imaginary surface that separates the system from its surroundings is called the boundary. These terms are illustrated in Fig. 1–1. The boundary of a system can be fixed or movable. Note that the boundary is the contact surface shared by both the system and the surroundings. Mathematically speaking, the boundary has zero thickness, and thus it can neither contain any mass nor occupy any volume in space.

Systems may be considered to be closed or open, depending on whether a fixed mass or a fixed volume in space is chosen for study. A closed system (also known as a control mass) consists of a fixed amount of mass, and no mass can cross its boundary. That is, no mass can enter or leave a closed system, as shown

But energy, in the form of heat or work, can cross the boundary; and the volume of a closed system does not have to be fixed. If, as a special case, even energy is not allowed to cross the boundary, that system is called an isolated system. Consider the piston-cylinder device shown. Let us say that we would like to find out what happens to the enclosed gas when it is heated. Since we are focusing our attention on the gas, it is our system.

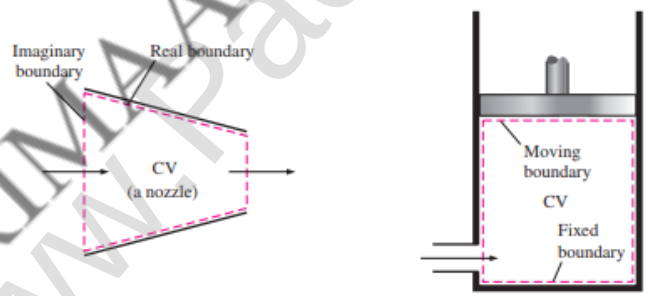
The inner surfaces of the piston and the cylinder form the boundary, and since no mass is crossing this boundary, it is a closed system. Notice that energy may cross the boundary, and part of the boundary (the inner surface of the piston, in this case) may move. Everything outside the gas, including the piston and the cylinder, is the surroundings. An open system, or a control volume, as it is often called, is a properly selected region in space.

It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle. Flow through these devices is best studied by selecting the region within the device as the control volume. Both mass and energy can cross the boundary of a control volume.

A large number of engineering problems involve mass flow in and out of a system and, therefore, are modeled as control volumes. A water heater, a car radiator, a turbine, and a compressor all involve mass flow and should be analyzed as

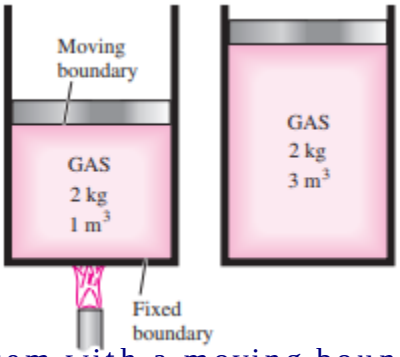
control volumes (open systems) instead of as control masses (closed systems). In general, any arbitrary region in space can be selected as a control volume. There are no concrete rules for the selection of control volumes, but the proper choice certainly makes the analysis much easier. If we were to analyze the flow of air through a nozzle, for example, a good choice for the control volume would be the region within the nozzle. The boundaries of a control volume are called a control surface, and they can be real or imaginary. In the case of a nozzle, the inner surface of the nozzle forms the real part of the boundary, and the entrance and exit areas form the imaginary part, since there are no physical surfaces there A control volume can be fixed in size and shape, as in the case of a nozzle, or it may involve a moving boundary,

Most control volumes, however, have fixed boundaries and thus do not involve any moving boundaries. A control volume can also involve heat and work interactions just as a closed system, in addition to mass interaction. As an example of an open system, consider the water heater Let us say that we would like to determine how much heat we must transfer to the water in the tank in order to supply a steady stream of hot water. Since hot water will leave the tank and be replaced by cold water, it is not convenient to choose a fixed mass as our system for the analysis. Instead, we can concentrate our attention on the volume formed by the interior surfaces of the tank and consider the hot and cold water streams as mass leaving and entering the control volume. The interior surfaces of the tank form the control surface for this case, and mass is crossing the control surface at two locations.

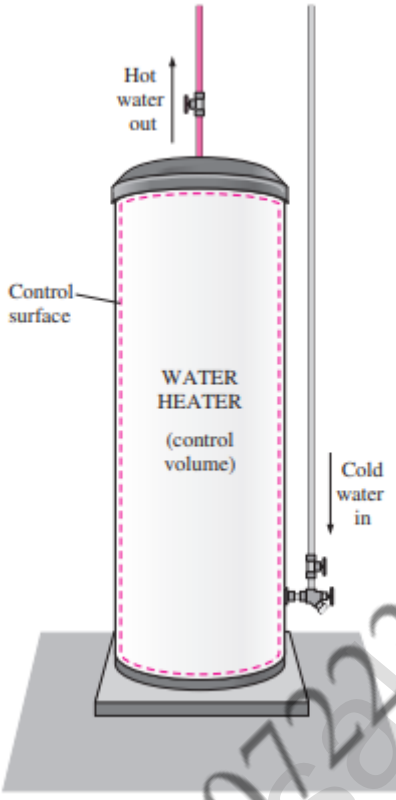


(a) A control volume with real and imaginary boundaries (b) A control volume with fixed and moving boundaries

A control volume can involve fixed, moving, real, and imaginary boundaries.



A closed system with a moving boundary

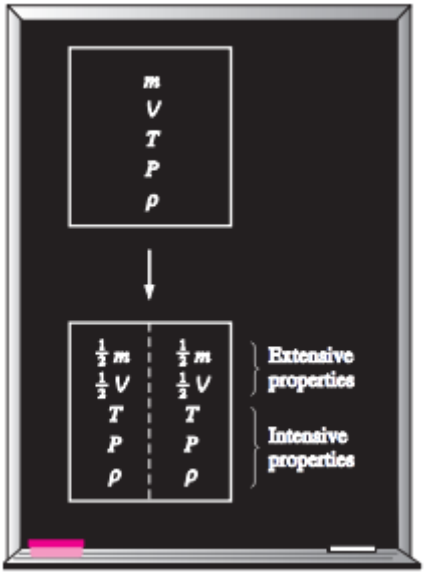


An open system (a control volume) with one inlet and one exit.

PROPERTIES OF A SYSTEM

Any characteristic of a system is called a property. Some familiar properties are pressure P, temperature T, volume V, and mass m. The list can be extended to include less familiar ones such as viscosity, thermal conductivity, modulus of elasticity, thermal expansion coefficient, electric resistivity, and even velocity and elevation. Properties are considered to be either intensive or extensive. Intensive properties are those that are independent of the mass of a system, such as temperature, pressure, and density. Extensive properties are those whose values depend on the size—or extent—of the system. Total mass, total volume, and total momentum are some examples of extensive properties. An easy way to determine whether a property is intensive or extensive is to divide the system into two equal parts with an imaginary partition,

Each part will have the same value of intensive properties as the original system, but half the value of the extensive properties. Generally, uppercase letters are used to denote extensive properties and lowercase letters are used for intensive properties, Extensive properties per unit mass are called specific properties. Some examples of specific properties are specific volume (v V/m) and specific total energy (e E/m).



Criterion to differentiate intensive and extensive properties.

CONTINUUM:

Continuum Matter is made up of atoms that are widely spaced in the gas phase. Yet it is very convenient to disregard the atomic nature of a substance and view it as a continuous, homogeneous matter with no holes, that is, a continuum. The continuum idealization allows us to treat properties as point functions and to assume the properties vary continually in space with no jump discontinuities. This idealization is valid as long as the size of the system we deal with is large relative to the space between the molecules. This is the case in practically all problems, except some specialized ones. The continuum idealization is implicit in many statements we make, such as "the density of water in a glass is the same at any point."

STATE AND EQUILIBRIUM:

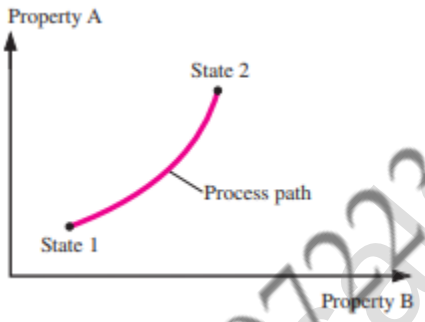
Consider a system not undergoing any change. At this point, all the properties can be measured or calculated throughout the entire system, which gives us a set of properties that completely describes the condition, or the state, of the system. At a given state, all the properties of a system have fixed values. If the value of even one property changes, the state will change to a different one.

* A system is shown at two different states.
* Thermodynamics deals with equilibrium states.

The word equilibrium implies a state of balance. In an equilibrium state there are no unbalanced potentials within the system. A system in equilibrium experiences no changes when it is isolated from its surroundings. There are many types of equilibrium, and a system is not in thermodynamic equilibrium unless the conditions of all the relevant types of equilibrium are satisfied.

PROCESSES AND CYCLES

Any change that a system undergoes from one equilibrium state to another is called a process, and the series of states through which a system passes during a process is called the path of the process (Fig. 1–6). To describe a process completely, one should specify the initial and final states of the process, as well as the path it follows, and the interactions with the surroundings. When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times, it is called a quasistatic, or quasi-equilibrium, process. A quasi-equilibrium process can be viewed as a sufficiently slow process that allows 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.



A process between states 1 and 2 and the process path.

When a gas in a piston-cylinder device is compressed suddenly, the molecules near the face of the piston will not have enough time to escape and they will have to pile up in a small region in front of the piston, thus creating a high-pressure region there.

Because of this pressure difference, the system can no longer be said to be in equilibrium, and this makes the entire process nonquasi-equilibrium. However, if the piston is moved slowly, the molecules will have sufficient time to redistribute and there will not be a molecule pileup in front of the piston.

As a result, the pressure inside the cylinder will always be nearly uniform and will rise at the same rate at all locations. Since equilibrium is maintained at all times, this is a quasi-equilibrium process. It should be pointed out that a quasi-equilibrium process is an idealized process and is not a true representation of an actual process. But many actual processes closely approximate it, and they can be modeled as quasiequilibrium with negligible error. Engineers are interested in quasiequilibrium processes for two reasons. First, they are easy to analyze; second,work-producing devices deliver the most work when they operate on quasiequilibrium processes. Therefore, quasi-equilibrium processes serve as standards to which actual processes can be compared. Process diagrams plotted by employing thermodynamic properties as coordinates are very useful in visualizing the processes. Some common properties that are used as

coordinates are temperature T, pressure P, and volume V (or specific volume v).

Shows the P-V diagram of a compression process of a gas. Note that the process path indicates a series of equilibrium states through which the system passes during a process and has significance for quasie-quilibrium processes only. For nonquasi-equilibrium processes, we are not able to characterize the entire system by a single state, and thus we cannot speak of a process path for a system as a whole.

* A nonquasi-equilibrium process is denoted by a dashed line between the initial and final states instead of a solid line.

* The prefix iso- is often used to designate a process for which a particular property remains constant.

An isothermal process, for example, is a process during which the temperature T remains constant; an isobaric process is a process during which the pressure P remains constant; and an isochoric (or isometric) process is a process during which the specific volume v remains constant.

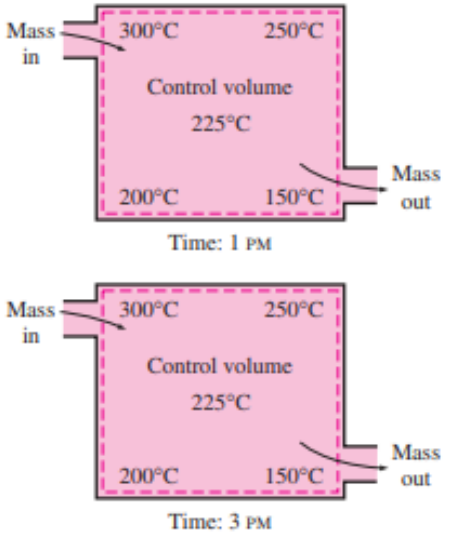
A system is said to have undergone a cycle if it returns to its initial state at the end of the process. That is, for a cycle the initial and final states are identical.

The Steady-Flow Process:

The terms steady and uniform are used frequently in engineering, and thus it is important to have a clear understanding of their meanings. The term steady implies no change with time. The opposite of steady is unsteady, or transient. The term uniform, however, implies no change with location over a specified region. These meanings are consistent with their everyday use (steady girlfriend, uniform properties, etc.).

A large number of engineering devices operate for long periods of time under the same conditions, and they are classified as steady-flow devices. Processes involving such devices can be represented reasonably well by a somewhat idealized process, called the steady-flow process, which can be defined as a process during which a fluid flows through a control volume steadily (Fig. 1–9). That is, the fluid properties can change from point to point within the control volume, but at any fixed point they remain the same during the entire process. Therefore, the volume V, the mass m, and the total energy content E of the control volume remain constant during a steadyflow process.

Steady-flow conditions can be closely approximated by devices that are intended for continuous operation such as turbines, pumps, boilers, condensers, and heat exchangers or power plants or refrigeration systems. Some cyclic devices, such as reciprocating engines or compressors, do not satisfy any of the conditions stated above since the flow at the inlets and the exits will be pulsating and not steady. However, the fluid properties vary with time in a periodic manner, and the flow through these devices can still be analyzed as a steady-flow process by using time-averaged values for the properties.



During a steady-flow process, fluid properties within the control volume may change with position but not with time.

TEMPERATURE AND THE ZEROTH LAW OF THERMODYNAMICS:

Although we are familiar with temperature as a measure of "hotness" or "coldness," it is not easy to give an exact definition for it. Based on our physiological sensations, we express the level of temperature qualitatively with words like freezing cold, cold, warm, hot, and red-hot. However, we cannot assign numerical values to temperatures based on our sensations alone. Furthermore, our senses may be misleading. A metal chair, for example, will feel much colder than a wooden one even when both are at the same temperature.

Fortunately, several properties of materials change with temperature in a repeatable and predictable way, and this forms the basis for accurate temperature measurement. The commonly used mercury-in-glass thermometer, for example, is based on the expansion of mercury with temperature. Temperature is also measured by using several other temperature-dependent properties.

It is a common experience that a cup of hot coffee left on the table eventually cools off and a cold drink eventually warms up. That is, when a body is brought into contact with another body that is at a different temperature, heat is transferred from the body at higher temperature to the one at lower temperature until both bodies attain the same temperature At that point, the heat transfer stops, and the two bodies are said to have reached thermal equilibrium. The equality of temperature is the only requirement for thermal equilibrium.

Two bodies reaching thermal equilibrium after being brought into contact in an isolated enclosure

The zeroth law of thermodynamics states that if two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other. It may seem silly that such an obvious fact is called one of the basic laws of thermodynamics. However, it cannot be concluded from the other laws of thermodynamics, and it serves as a basis for the validity of temperature measurement. By replacing the third body with a thermometer, the zeroth law can be restated as two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.

The zeroth law was first formulated and labeled by R. H. Fowler in 1931. As the name suggests, its value as a fundamental physical principle was recognized more than half a century after the formulation of the first and the second laws of thermodynamics. It was named the zeroth law since it should have preceded the first and the second laws of thermodynamics.

To be continued.....

UG-TRB MATERIALS

GRADUATE TEACHERS / BLOCK RESOURCE TEACHER EDUCATORS (BRTE) & SGT

- UG TRB: TAMIL MATERIAL WITH QUESTION BANK.
- UG TRB: ENGLISH STUDY MATERIAL +Q. BANK.
- UG-TRB: MATHEMATICS MATERIAL WITH Q. BANK (E/M)
- UG TRB: PHYSICS MATERIAL WITH QUESTION BANK (E/M)
- UG TRB: CHEMISTRY MATERIAL + QUESTION BANK (E/M)
- UG TRB: HISTORY MATERIAL + Q.BANK (E/M)
- UG TRB: ZOOLOGY MATERIAL + QUESTION BANK (E/M)
- UG TRB: BOTANY MATERIAL +QUESTION BANK (T/M& E/M)
- UG TRB: GEOGRAPHY STUDY MATERIAL (E/M)

SCERT/DIET/GTTI (LECTURER) STUDY MATERIAL AVAILABLE.

TRB-POLYTECHNIC LECTURER-(NEW SYLLABUS) STUDY MATERIALS AVAILABLE

- MATHEMATICS STUDY MATERIAL with Question Bank.
- ENGLISH STUDY MATERIAL with Question Bank.
- PHYSICS STUDY MATERIAL with Question Bank.