

Macroscopic:- Analysis of a thermodynamic system made by the measurable properties such as pressure, volume etc of the system is termed as Macroscopic point of view.

Microscopic:- It focus on statical behaviour of mass consisting of numerous individual molecules. or

It correlates macroscopic properties of the matter with molecular configuration and with intermolecular forces.

Thermodynamic Equilibrium:-

- a) Mechanical equilibrium (no-unbalanced force)
- b) Chemical equilibrium (no-chemical reaction)
- c) Thermal equilibrium (uniform temp)
- d) Electrical equilibrium (uniform electric field)

Concept of Continuum:-

### Thermodynamic System:-

or It is defined as a specified region of space wherein changes due to transfer of mass or energy or both are to be studied.

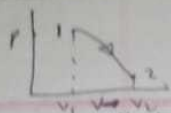
In a system it is not necessary that the volume or shape should remain ~~constant~~ fixed.

closed system:- Mass within the boundary of the system remains constant and only energy (heat and work) may transfer across its boundary. eg: Gas confined between piston and cylinder.

Open system:- Mass as well as the heat energy (heat and work) transfer across its boundaries. eg: Compressor, nozzle, diffuser, steam engine, i.c. engine.

Control volume:- When attention is focused on fixed region in space is called control volume, through which mass, momentum and energy may flow. and boundaries of control volume are called control surface.

Isolated system:- in which neither mass nor energy (heat and work) transfers across the boundary. eg: Thermos flask.



represented by the area underneath the corresponding path.

This suggests that work is not a property of a state function rather it is a path function.  $\delta W$  is an inexact or imperfect differential.  $\delta W \neq W_2 - W_1$ . Heat - It is the energy transferred without transfer of mass, across the boundary of system because of temperature difference between system and surroundings.

Point function: Thermodynamic properties are point function. Since for a given state there is a definite value for each property.

The change in thermodynamic property of a system in a change of state is independent of the path of the system followed during the change of state and depends only on the initial and final value of the system. The differential of point function are exact

or perfect and integration is simply  $\int_{V_1}^{V_2} P dV = W_2 - W_1$ .

### Measurement of Temperature

Equality of temperature:-

In order to understand equality of temperature or a method of defining and measuring temperature. Consider, two systems A and B perfectly insulated from surrounding. Both of them are brought in good contact, the energy in the form of heat will transfer from the body at a higher temperature to the body at lower temperature. After sufficient time has elapsed the bodies A and B will approach a state at which no further change is observed. The two bodies are then in a state of thermal equilibrium. At this point the two systems are said to be at the same temperature. This is called Equality of temperature or Basis of Temperature Measurement.

### Zeroth law of thermodynamics:-

"If two systems are each in thermal equilibrium with a third system, they are also in thermal equilibrium with each other." This statement is known as the zeroth law of thermodynamics and is the basis of concept of temperature as well as the basis of all temperature measurement. The third body is called the thermometer.

### Principle of thermometry:-

Thermometry may be defined as the art or device of measuring temperature with scientific precision.

The basic principle of thermometry is that the two bodies in contact and in thermal equilibrium have the same temperature.

Generally heat is transferred to a

measuring instrument and the change due to temperature is measured in some property is recorded.

A property which changes in value as a function of temperature is called thermometric property.

### Temperature Scale:-

In order to measure the temperature of a system by an instrument such as thermometer a temperature scale must be provided on the thermometer (i.e. assigning numerical to the thermometer).

Since temperature is a property it has a unique value at each equilibrium state of the system.

### Reference point (fixed point)

First is to select suitable thermo-

thermometric property and then the form of variation of thermometric property as a function of temperature and finally to select the Reference point or fixed point.

eg: 2

Now let us consider for simplicity that the temperature  $t$  is a linear function of thermometric property  $x$  (e.g. length of Hg column).

Then the form of variation may be  $t = ax + b$  or  $t = ax$ . - (1)

where  $a$  and  $b$  are arbitrary constant.

Let ice point and the steam point at one atmospheric pressure as the two fixed points for fixing the scale. Let these temperatures be  $t_i$  and  $t_s$  and corresponding thermometric property be  $x_i$  and  $x_s$ . So eq (1) takes the form  $t_i = ax_i + b$ . - (2)

$t_s = ax_s + b$ . - (3)

Now thermometer is placed in contact with the system whose temperature  $t$  is to be measured. Then  $t = ax + b$ . - (4)

Solving eq (2) & (4).

$$t - t_i = ax + b - ax_i - b$$

$$t - t_i = a(x - x_i) \Rightarrow a = \frac{t - t_i}{x - x_i} \quad - (5)$$

$$\text{again, } t_s - t_i = ax_s + b - ax_i - b$$

$$a = \frac{t_s - t_i}{x_s - x_i} \quad - (6)$$

Equating 5 and 6.

$$\frac{t - t_i}{x - x_i} = \frac{t_s - t_i}{x_s - x_i}$$

$$t = t_i + \frac{t_s - t_i}{x_s - x_i} (x - x_i)$$

$$t = t_i + \frac{t_s - t_i}{x_s - x_i} (x - x_i)$$

$$\text{If } x = \text{Cie (e.g. length of column)},$$

$$t = t_i + \frac{t_s - t_i}{(1 - t_i)}$$



Considering the pure water at 100°C  
 The fixed point assigned to the air  
 and steam point are 0°C and 100°C  
 respectively (for pure water).  
 $t_F = 0^\circ \text{C}$  &  $t_C = 100^\circ \text{C}$   
 The fixed equation is  

$$\frac{t_F - L_F}{L_F - L_1} = \frac{t_C - L_C}{L_C - L_1}$$

$$\frac{t_F - 0}{100 - L_1} = \frac{t_C - 100}{100 - L_1}$$

$$\therefore t_F = 0 + \left( \frac{L_F - L_1}{100 - L_1} \right) (100 - L_1)$$

$$t = - \frac{L_F - L_1}{100 - L_1} (L - L_1)$$

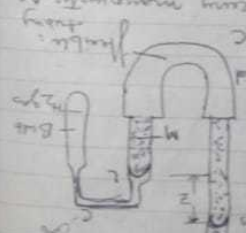
$$t_C = \left( \frac{L_C - L_1}{L_F - L_1} \right) \times 100$$
 Relation between scales of temperature is  
 $t_C = \frac{9}{5} (t_F - 32)$   
 $t_F = \frac{5}{9} (t_C + 32)$   
 $t_F = 0^\circ \text{C} + 273.16$   
 $t_C = 32^\circ \text{F}$

Triple point of H<sub>2</sub>O as reference point  
 The state at which ice, liquid water  
 and water vapour coexist in equilibrium  
 is 273.16 K.  
 Designating the triple point of water  
 by  $t_t$  and  $L_t$  being the value of temperature  
 at property. Then  
 the body whose temperature  $t$  is  
 to be measured is placed in contact with  
 water triple point of water (ice + water)  
 $t_t = a x_t$  and  $t = a x$   
 $a = \frac{t_t}{x_t}$   
 $a = \frac{x}{t}$   
 Equating  
 $\frac{t_t}{x_t} \times x = \frac{t}{273.16} \times 273.16$   
 $t = \frac{273.16}{x_t} \times x$   
 This is the standard form  
 of the equation of the  
 property

Ideal gas thermometer  
 A gas thermometer is a device for measuring temperature in terms of pressure of a gas. It consists of a bulb of known volume containing a gas, connected by a tube to a U-tube manometer. The gas pressure is measured by the height difference in the manometer liquid. The pressure in the bulb is a measure of temperature in bulb. Hence pressure in bulb is used as a thermometric property and given by  $P = P_0 + \rho g h$  where  $P_0$  = density of Hg and  $P_0$  atmospheric pressure.

Such that it just touches the bulb. It is vertically to adjust the measuring level open to atmosphere, and can be moved with one end of the measuring manometer. The other end of bulb is connected through capillary tube C. A small amount of gas is enclosed in bulb B, which is connected to the gas. The gas is enclosed in bulb B, which is connected to the gas. The gas is enclosed in bulb B, which is connected to the gas.

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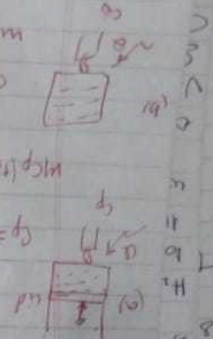
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Heat transfer may be regarded as energy interaction between two - closed systems which have no work interaction. The work heat again is possible.

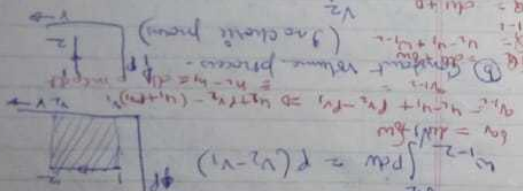


$$Q = \int_{V_1}^{V_2} p \, dV$$

$$W = \int_{V_1}^{V_2} p \, dV$$

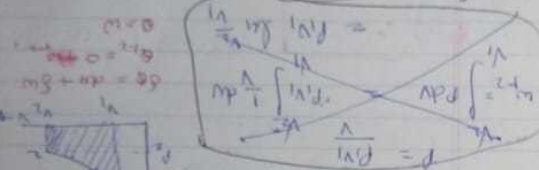
First law applicable to closed systems.  $P \, dV$  - work in various quasi-static process.

② constant pressure process (isobaric)



$$W = \int_{V_1}^{V_2} P \, dV = P(V_2 - V_1)$$

$$Q = \Delta U + W$$



$$W = \int_{V_1}^{V_2} P \, dV = 0$$

$$Q = \Delta U$$



Potential Energy:- Energy due to position and elevation of mass with respect to earth. A force " $F$ " is exerted on a mass " $m$ " due to gravitational attraction " $g$ " at elevation " $z$ " from earth surface is  $F = mgz$ .

Kinetic Energy:- Energy created from the motion of a mass.  $= \frac{mv^2}{2}$

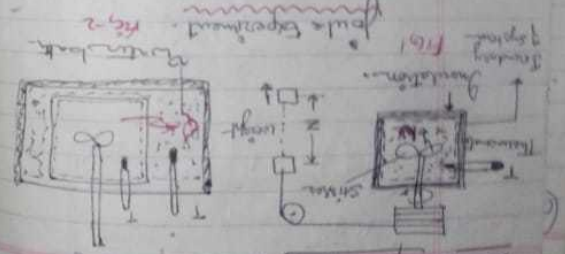
Internal Energy:- Energy associated with the configuration and motion of its molecules, atoms and sub atomic particles relative to its centre of mass.

Work:- defined as energy transferred without transfer of mass across the boundary of a system.

path function:- work interaction is

A quantity of liquid is kept in an insulated vessel. Work is done on fluid by stirring. The paddle wheel. This work input to the fluid causes a rise in its temperature & the fluid. The amount of work done on the fluid is calculated by its product of its weight and the vertical height through which the weight descends.

Next by knowing the height in the system, the system is immersed in a water.



Joule's Experiment :-

The work input is directly proportional to the heat loss & transferred from the system.

First law of thermodynamics :-  
 At the system under goes a cyclic change then the algebraic sum of the work obtained & the surrounding & the algebraic sum of heat taken from the surrounding is equal to zero.

The amount of heat rejected by the fluid is equal to the increase of energy of the fluid. The system undergoes a cyclic cycle. The temperature and pressure, in this way, of the liquid & heat lost will be maintained. Both heat & heat is transferred from the liquid to the original state.

The work input is directly proportional to the heat loss & transferred from the system.

Heat lost =  $\oint \delta Q = \oint \delta W$

First law of thermodynamics is the

law of conservation of energy

ie energy can neither be created

nor destroyed but only converted

from one form to another

$\delta Q - \delta W = dE$  if constant

it is impossible to construct a perpetual

motion machine of the first kind.

ie PMM-1 is not possible.

PMM-1 is capable of producing energy with

out corresponding expenditure of energy.

First law of thermodynamics is that the

energy of a system is conserved

First law applied to (process) closed system

Control mass of first law of thermodynamics

Consider a closed system which

undergoes a change of state from 1 to 2 as

shown in (ie-process 1-2)

The system may proceed from state

1 to state 2 along the path A and then

return back to state 1 along the path B

Thus say a cycle is completed

after a cycle (A-B-A)

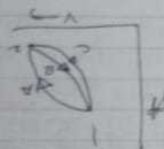
Two form first law

$$\oint \delta Q = \oint \delta W$$

$$\oint \delta Q - \delta W = 0$$

$$\text{or } \int_1^2 (\delta Q - \delta W)_A = \int_2^1 (\delta Q - \delta W)_B = 0$$

Equivalently per cycle 1-2-1



$$\int_1^2 (\delta Q - \delta W) = \int_1^2 [du + dKE + dPE]$$

system. Two for non flow process.

This is called total energy  $E$  (the sum of internal energy, kinetic energy, and potential energy).

fixed by the end state, and is independent of the path taken.

\* Thus the value of  $\int_1^2 (\delta Q - \delta W)$  is solely a function of the end states, i.e. location in system.

(quantity  $\int_1^2 (\delta Q - \delta W)$  is a constant value - The above (3) suggest that when a system operates between state 1 and 2, the value of  $\int_1^2 (\delta Q - \delta W)$  is a constant value.)

$$\int_1^2 (\delta Q - \delta W)_a = \int_1^2 (\delta Q - \delta W)_b = \dots$$

Comparing above three equations.

$$\int_1^2 (\delta Q - \delta W)_a + \int_1^2 (\delta Q - \delta W)_b = 0 \quad (1)$$

$$\delta E = d(u + KE + PE)$$

$$Q = u + PV$$

$$(Q)P = h$$

as  $H = U + PV$  the unit mass  $h = u + PV$  KJ/kg

Enthalpy: - entropy (substance H) degree of freedom are called enthalpies.

The conclusions of first laws of Thermodynamics are called enthalpies.

Two first laws enables us to define a property of the system called internal energy. When applied to a process.

The conclusions of first laws of Thermodynamics are called enthalpies.

$$Q_{1-2} - W_{1-2} = U_2 - U_1$$

$$\delta Q - \delta W = du$$

$$\int_1^2 \delta Q - \delta W = \int_1^2 du$$

System. In the absence of K.E. P.E. and closed

The function  $f(z)$  is analytic in the region  $|z| < 1$  and has a removable singularity at  $z = 1$ . The function  $f(z)$  is analytic in the region  $|z| < 1$  and has a removable singularity at  $z = 1$ . The function  $f(z)$  is analytic in the region  $|z| < 1$  and has a removable singularity at  $z = 1$ .

$$\lim_{z \rightarrow 1} \left( \frac{f(z)}{z-1} \right) = \lim_{z \rightarrow 1} \left( \frac{z-1}{z-1} \right) = 1$$

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$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

This mass balance is called continuity equation of a fluid flowing steadily through a pipe.

$A$  = Area of cross section of fluid flow at entrance and exit  $m^2$

$V$  = Specific volume  $m^3/kg$  at entrance and exit

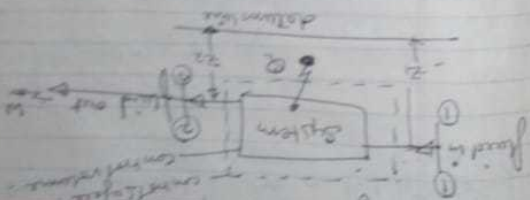
$V$  = velocity of fluid at entrance and exit  $m/s$

$$\rho_1 + \rho_2 = \rho_3$$

$$\rho_1 + \rho_2 = \rho_3$$

$$\rho_1 + \rho_2 = \rho_3$$

Consider a control volume of a fluid flowing through a pipe. The fluid is at rest in the control volume. The fluid is at rest in the control volume. The fluid is at rest in the control volume.



Steady flow energy equation

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regulation.

Run is called steady flow exactly

$$x_1 b + \frac{x_2}{2} + x_3 + w = \frac{1}{2} b + \frac{1}{2} + 1 + 1$$

first limit mass  $m$  ( $m=1 \text{ kg}$ )

$$\left[ 4b - \frac{1}{2} - 4 - 2b + \frac{2}{2} + 2 \right] m = m - 2$$

$$4/4 - \frac{7}{24} - 1/4 = 2/3 + \frac{7}{24} + 1/4 \text{ @ } \text{The} =$$

$$1\frac{1}{2} - 2\frac{1}{2} = m - 0$$

① No cost

$$\sqrt{\frac{2}{m} \times \frac{1}{2} \times m \times v^2} + \Delta H = \sqrt{\frac{2}{m} \times \frac{1}{2} \times m \times v^2} + \Delta H + \Delta G$$

Specify heat for heat space  
Specify heat & a property value  
to internal energy, both very important in  
thermodynamics.  
The intensive properties  $\rho$ , and  $\rho_0$  are  
defined for pure simple compressible substances  
and partial derivatives of the internal energy  
 $u(T, v)$  and enthalpy  $h(T, p)$  respectively.

$$\frac{1}{\left(\frac{1}{2}\right)^2} = 4 \quad 2^{\frac{1}{\left(\frac{1}{2}\right)^2}} = 2^4 = 16$$

Energy - Capacity to exert force through a distance, i.e. capacity to do work.

Newton first hypothesized about the

Energy is a scalar quantity. It cannot

be observed but can be measured and

calculated by indirect measurement.

The dimension of energy is  $E = L^2 M T^{-2}$

Energy are classified as stored energy and

energy in transition.

③ Stored energy - It is contained within a

system boundary eg. PE, KE & IE.

Also called energy in state.

② Energy in transition - It crosses the

system boundary eg. heat, work & radiation.

Energy types -

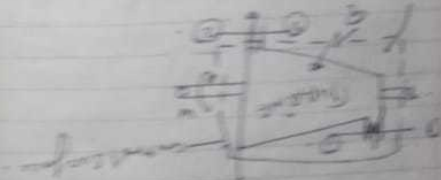
KE I.E.







First class highest level



we have seen the application of  
 the cell wall in the process of  
 growth. But now the expanding cell  
 wall in the cytoplasmic region, called  
 functional points, sometimes as cytoplasmic  
 working fluid. Sometimes there is a point  
 of the cytoplasmic fluid, such as plasma  
 and cell wall process and to system.  
 & cell wall open system.

10. 11. 1950

1. Show the first column and last  
 the first column is same and last  
 row is same  $m = n$   
 and  
 2. To find  $y$  to last column and  
 leaving the first column same in  
 row with  $b$  and row strong in  
 row with  $a$  to find value  
 3. To get  $z$  from strong  
 row (strong) to  $a$  and  $b$   
 row with  $b$

Path (16)

A thermodynamic system passing through a series of states constitutes a path.

State (15)

It is the condition of a system at an instant of time described by its properties.

Process (14)

It is defined as a transition in which a system changes from one initial state to final state.

Cycle (13)

If the properties of the system at the end of the process are same as at the beginning is called the cycle or cyclic process.

Quasi-Static (12)

A process closely approximating to a

Succession of equilibrium states is known as Quasi-Static process.

Reversible (11)

A process is reversible if the system passes through a continuous series of equilibrium states. Or - If the initial state together with all energies transferred or transformed during the process can be completely restored in both system and environment.

\* If a system passes through a sequence of non-equilibrium states then the process is irreversible.

Pure Substance (10)

Characteristics of a substance is that it has a homogeneous composition irrespective of the phase in which it exists.

pure substance is also called as single component system.

Thermal power plant operates with the help of some working fluid (steam) called pure substance.

It is the change in properties of the working fluid (pure substance) which operates the power plant.

Refrigerants are also called pure substances,

It is the changes in properties of refrigerant (pure substance) that causes the cooling effect.

### Control volume

defined region in space through which mass, momentum and energy may flow & called Control volume

Specific volume is defined as the volume per unit mass.

### Equilibrium:

A system is said to be in a state of thermodynamic equilibrium if the value of the property is same at all points of the system.

A system is said to be in a state of mechanical equilibrium if there exist no unbalanced force either in the interior of the system or between the system and surrounding.

A system is said to be in a state of chemical equilibrium if there exist no chemical reaction or mass exchange

from one part of the system to another.

A system is said to be in a state of thermal equilibrium if there exist a uniformity of temperature between the system and the surrounding.

### Property

measurable characteristics associated with the system & called the property of system. Temperature, Pressure, Volume, Entropy, Surface area.

Intensive property is one in which the value of the property does not depend upon the mass of the system.

eg. Temp, Pressure, Density, Viscosity and Refractive index.

If the value of the property depends upon the mass of the system & called the extensive property.

eg. Mass, Area, Volume, I.O, H.E and P.E.