

**RPSC - A.En.**

← Assistant Engineering →

**MECHANICAL**

**Rajasthan Public Service Commission (RPSC)**

**Volume - 6**

**Thermodynamics**



# BASIC CONCEPTS

## THEORY

### 1.1 WHAT IS THERMODYNAMICS

Thermodynamics is the science of energy transfer and its effect on the physical properties of substances. It is based upon observation of common experience which have been formulated into thermodynamics laws. These law govern the principle found in all fields of energy technology, notable in steam and nuclear power plants, Internal combustion engine, gas turbines, air conditioning, refrigeration, gas dynamics, jet propulsion, compressor, chemical process plants and direct energy conversion devices.

### 1.2 ETYMOLOGY

The etymology of thermodynamics has an intricate history. It was first spelled in hyphenated form as an adjective (Thermo-dynamic) and from 1854 to 1868 as the noun Thermodynamics to represent, “The science of heat engines”.

American bio physicist Donald Haynie Claims that thermodynamics was coined in 1840 from the “Greek” root therme meaning ‘heat’ and ‘dynamics’ meaning power. However the etymology has been cited as unlikely

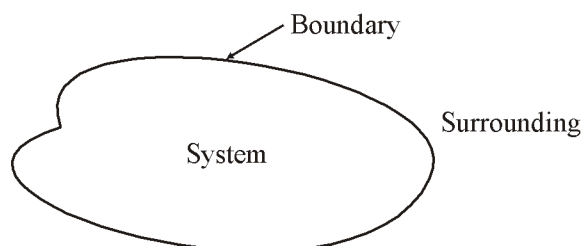
Pierre Parrot claims that the term thermodynamics was coined by James Joule in 1858 to designate. The science of relation between heat and power.

By 1858, thermodynamics, as functional term was used in William Thomson's paper “An Account of Carnot's Theory of Motive Power of Heat”.

### 1.3 THERMODYNAMIC SYSTEM AND SURROUNDINGS

An important concept in thermodynamics is the thermodynamic system, a precisely defined region of the universe under study. Everything in the universe, except the system is known as the surrounding.

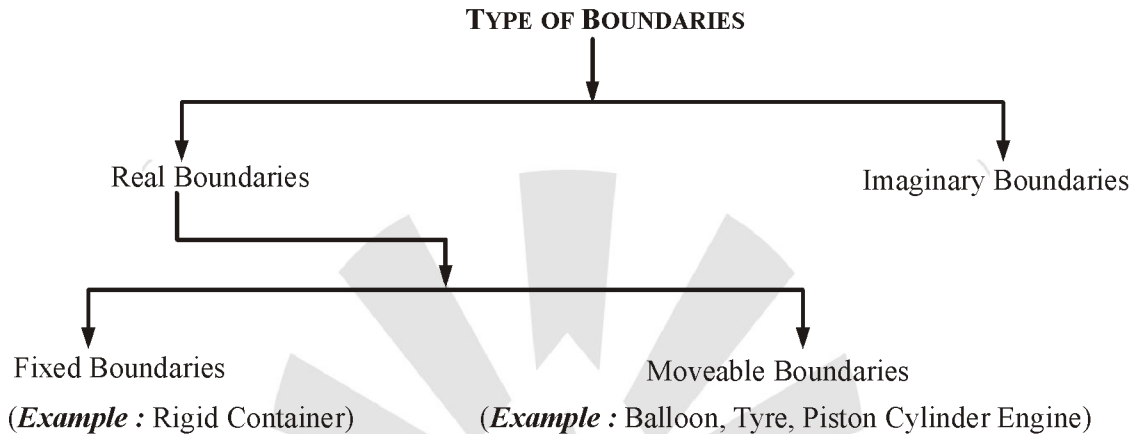
A system is separated from the remainder of the universe by a boundary which may be notional or not but which by convention delimits a finite volume. Exchanges of work, heat or matter between the system and the surrounding take place across this boundary.



System + Surrounding combined called universe

The boundary is simply a surface around the volume of interest. Any thing that passes across the boundary that effects a change in the internal energy need to be accounted for in the energy balance equation.

The volume can be the region surrounding a single atoms resonating energy. It can be the body of tropical cyclone. It could also be just one nuclide (i.e., system of quarks) as hypothesized in quantum thermodynamics.



**Note: Adiabatic wall :** It is a kind of wall made of insulator which will not allow heat transfer between system and surrounding.

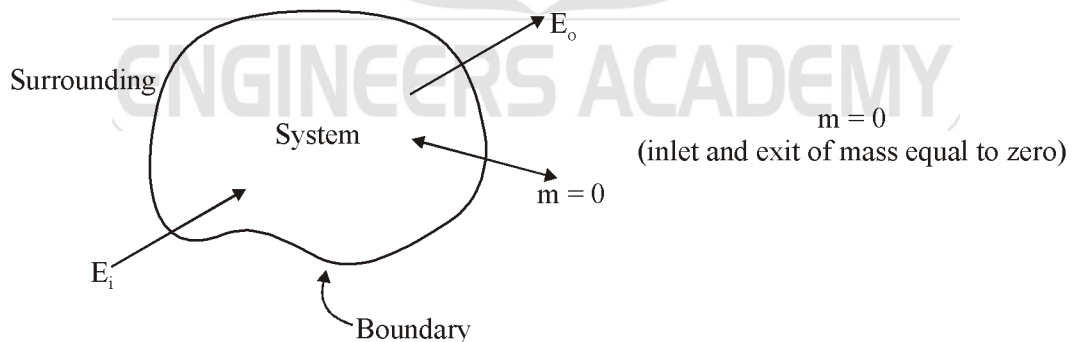
**Metalic Wall or Diathermic Wall :** It is a kind of wall made of conductor which will allow heat transfer between system and surrounding.

## 1.4 TYPES OF THERMODYNAMIC SYSTEM

There are three types of Thermodynamic system

### 1.4.1 CLOSED SYSTEM

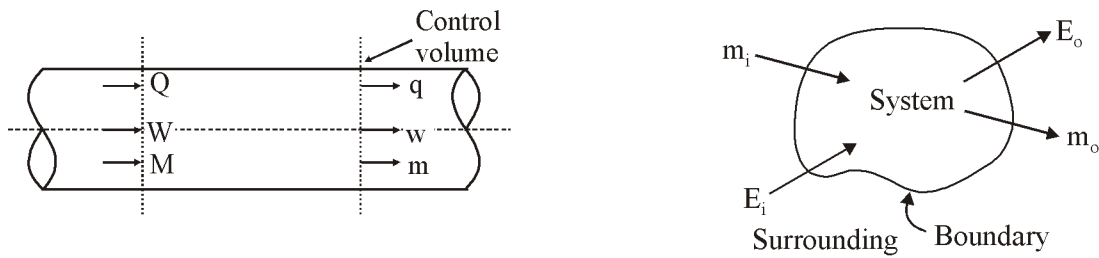
Energy in the form of heat and work can cross the boundary of the system, but there is no mass flow across the boundary. Boundary in closed system is control mass boundary.



**Example:** Piston cylinder arrangement without valve (heat and work cross the boundary but not mass)

### 1.4.2 OPEN SYSTEM

Both matter and energy can cross the boundary. Boundary use in these type of system is control volume boundary example flow of fluid in pipe



Heat, flow work and mass all can enter and leave the control volume

**Example:** Turbine, Pump, compressor, earth and its atmosphere etc.

Piston cylinder arrangement without valve.

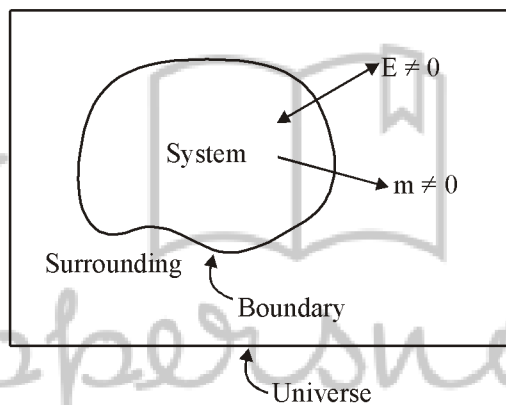
**1.4.3 ISOLATED SYSTEM**

A system that exchanges neither energy nor matter with its surrounding. In isolated system boundary of the system is adiabatic and control mass boundary

**Example:** Thermoflask, Universe

*Note: Most of the thermodynamic system is taken as control volume or open system.*

$$\text{Universe} = \text{System} + \text{Surrounding}$$



Hence universe is an e.g. of isolated system because no transfer of energy and matter takes place

**1.5 THERMODYNAMICS PROPERTIES**

Any measurable characteristics of the system is called the system Properties, properties of system define the position of system in space.

- All properties are point function
- Any variable whose change is fixed by the end states is a property (or we can say it an exact differential depends on limit only)

**1.5.1 INTENSIVE PROPERTIES**

It is the properties of the system which is independent of the mass or size of the system; pressure, temperature, specific enthalpy, specific entropy, density and velocity are examples since they are the same for the entire system or for parts of the system. If we bring two system together, intensive properties are not summed.

**1.5.2 EXTENSIVE PROPERTIES**

It is the properties of the system which depends on the mass of the system; volume, momentum and kinetic energy are example, if two system are brought together the extensive property of the new system is the sum of the extensive properties of the two system.

*Note: If we divide an extensive property by the mass a specific property results. The specific volume thus defined to be*

$$v = \frac{V}{m}$$

*We will generally use an uppercase letter to represent an extensive property (Exception 'm' for mass) and a lowercase letter to denote the associated intensive property.*

## 1.6 THERMODYNAMIC EQUILIBRIUM

A system is said to exist in a state of thermodynamic equilibrium when no change in any property is registered, if the system is isolated from its surroundings.

An isolated system always reaches in course of time a state of thermodynamic equilibrium and can never depart from it spontaneously.

Therefore, there can be no spontaneous change in any property if the system exist in an equilibrium state. Thermodynamics studies mainly the properties of physical system that are found in equilibrium states. A system will be in a state of thermodynamic equilibrium. If the conditions for the following three type of equilibrium are satisfied.

### 1.6.1 MECHANICAL EQUILIBRIUM

In the absence of any unbalanced force within system itself and also between the system and surrounding. The system is said to be in a state of mechanical equilibrium.

### 1.6.2 THERMAL EQUILIBRIUMS

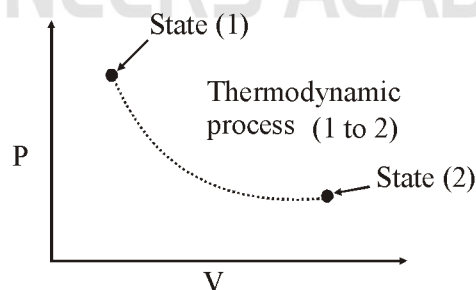
When a system existing in mechanical and chemical equilibrium is separated from its surroundings by a diathermic wall and if there is no spontaneous change in any property of the system. The system is said to exist in a state of thermal equilibrium.

### 1.6.3 CHEMICAL EQUILIBRIUM

If there is no chemical reaction or transfer of matter from one part of the system to another, such as diffusion or solution, the system is said to be exist in a state of chemical equilibrium.

## 1.7 THERMODYNAMIC PROCESS

When a system change its state from one equilibrium position to another equilibrium position it goes through a process, but these change is very fast and we cannot measure intermediate properties of the system. To measure intermediate properties thus we can assume quasi-static process.



Quasi-Static process

Quasi means 'Almost'

Static means 'Rest'

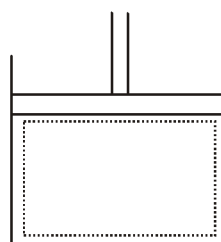
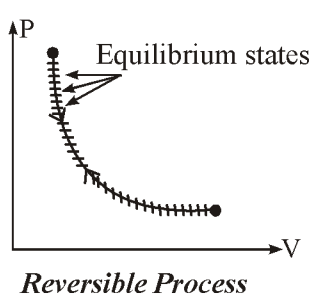
A process which carried out in a very slow manner with small difference in pressure is known as a quasi static process. To study the property change in between two state of the system we assume all thermodynamic process as quasi-static process

*Note: To represent the process on 2-D curve we take all properties as intensive properties to make process independent of the size of system.*

## 1.8 TYPE OF PROCESS

### 1.8.1 REVERSIBLE PROCESS

A reversible process (also sometimes known as quasi-static process) is one which can be stopped at any stage and reversed so that the system and surroundings are exactly restored to their initial states.



Friction less adiabatic piston cylinder engine is a follows reversible process

**This process has the following characteristics**

- (i) It must pass through the same states on the reversed path as were initially visited in the forward path.
- (ii) This process when undone will leave no history of events in the surroundings.
- (iii) It must pass through continuous series of equilibrium states.

No real process is truly reversible but some processes may approach reversibility, to close approximation.

**Examples:** Some examples of nearly reversible processes are :

- (1) Frictionless relative motion.
- (2) Expansion and compression of spring.
- (3) Frictionless adiabatic expansion or compression of fluid.
- (4) Polytropic expansion or compression of fluid.
- (5) Isothermal expansion or compression.
- (6) Electrolysis.

### 1.8.2 IRREVERSIBLE PROCESS

An irreversible process is one in which heat is transferred through a finite temperature.

**Irreversibility are of two types**

#### (i) External Irreversibilities

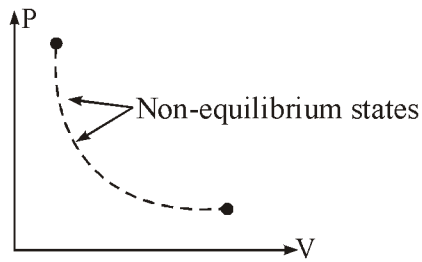
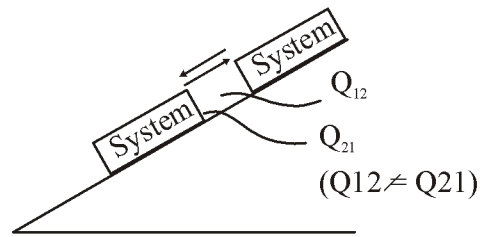
These are associated with dissipating effects outside the working fluid.

**Example:** Mechanical friction occurring during a process due to some external source.

#### (ii) Internal Irreversibilities

These are associated with dissipating effects within the working fluid.

**Example:** Unrestricted expansion of gas, viscosity and inertia of the gas.

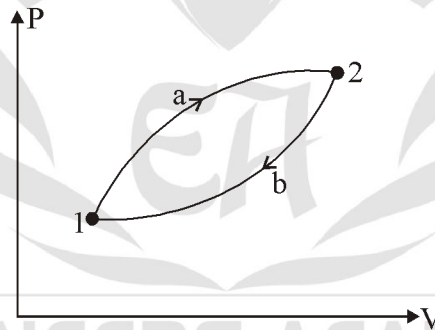
*Irreversible Process**It is irreversible process*

An irreversible process is usually represented by a dotted (or discontinuous) line joining the end states to indicate that the intermediate states are undetermined.

- Example:** (i) Relative motion with friction.  
 (2) Electricity flow through a resistance  
 (3) Plastic deformation  
 (4) Diffusion  
 (5) Throttling  
 (6) Heat transfer  
 (7) Combustion  
 (8) Free expansion

## 1.9 THERMODYNAMIC CYCLE

A system is said to have under goes a cycle if the initial and final point are same, Minimum number of process required for a cycle are two.



1-a-2-b-1 is a cycle

**Note:** The change in property in any cycle is equal to zero.

## 1.10 PURE SUBSTANCE

A pure substance is a system which is

### 1.10.1 HOMOGENEOUS IN COMPOSITION

The composition of each part of the system is the same as the composition of every other part. Composition means the relative proportions of the chemical elements into which the sample can be analysed. It does not matter how these elements are combined.

### 1.10.2 HOMOGENOUS IN CHEMICAL AGGREGATION

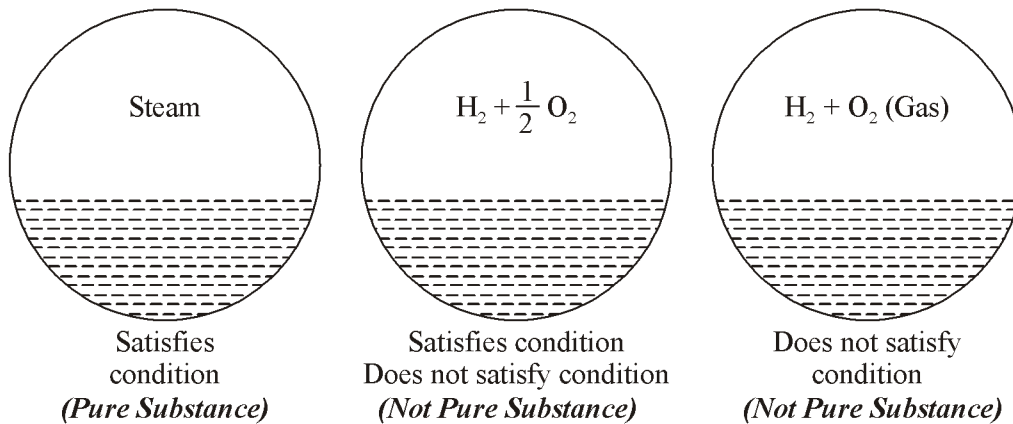
The chemical elements must be combined chemically in the same way in all parts of the system. Consideration of shown in figure that the system on the other hand is not homogeneous in chemical aggregation since in the upper part of the system the hydrogen and oxygen are not combined chemical

(individual atoms of H and O are not uniquely associated), where as in the lower part of the system the hydrogen and oxygen are combined to form water.

### 1.10.3 INVARIABLE IN CHEMICAL AGGREGATION

The state of chemical combination of the system does not change with time (condition referred to variation with position).

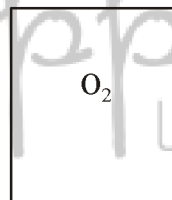
Thus a mixture of hydrogen and oxygen, which changed into steam during the time that the system was under consideration, would not be a pure substance.



**Note:** However that a uniform mixture of steam, hydrogen gas, and oxygen gas would be regarded as homogeneous in both composition and chemical aggregation whatever the relative proportions of the components.

### 1.11 GIBBS PHASE RULE

These use to measure degree of freedom of the system. That means how many independent properties required to fix the state of the system.

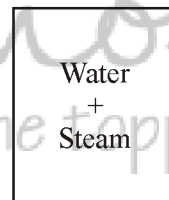


$$P = 1, C = 1$$

$$1 + F = 1 + 2$$

$F = 2$

It is pure substance also



$$P = 2, C = 1$$

$$2 + F = 1 + 2$$

$$F = 1$$

It is pure substance also

Gibbs Phase Rule Formula :

$$P + F = C + 2$$

Where,

P = Number of phase in the system

F = Degree of freedom of the system (minimum number of independent intensive properties required to fixed the state of the system)

C = Number of components in the system

**Note:** Generally pure substance has two degree of freedom so we can represent them in two dimension curve.



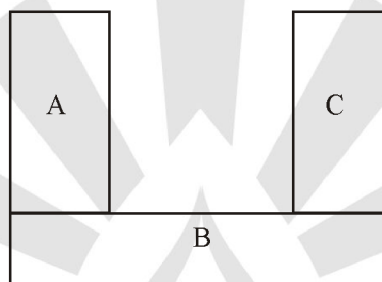
## 1.12 THERMODYNAMICS RULES

### 1.12.1 ZEROTH'S LAW OF THERMODYNAMICS

The property which distinguishes thermodynamics from other science is temperature. One might say that temperature bears an important a relation to thermodynamics as force do to static or velocity does to dynamics. Temperature is associated with the ability to distinguish hot from cold. When two bodies at different temperature are brought into contact, after some time they attain a common temperature and are then said to exist in thermal equilibrium.

**Statement :**

When a body A is in thermal equilibrium with body B, and also separately with a body C, then B and C will be in thermal equilibrium with each other.



$$T_A = T_B$$

$$T_B = T_C$$

$$T_A = T_C$$

*Note: When bodys A, B & C chemically react then zeroth law of thermodynamic will not apply.  
Zeroth law of thermodynamic help to find out temperature of the body.*

### 1.12.2 THERMOMETRIC PRINCIPAL

In order to obtain a quantitative measure of temperature, a reference body is used and a certain physical characteristic of this body which changes with temperature is selected. The change in the selected characteristic may be taken as an indication of change in temperature. The selected characteristic is called the thermometric property and the reference body which is used in the determination of temperature is called the thermometer.

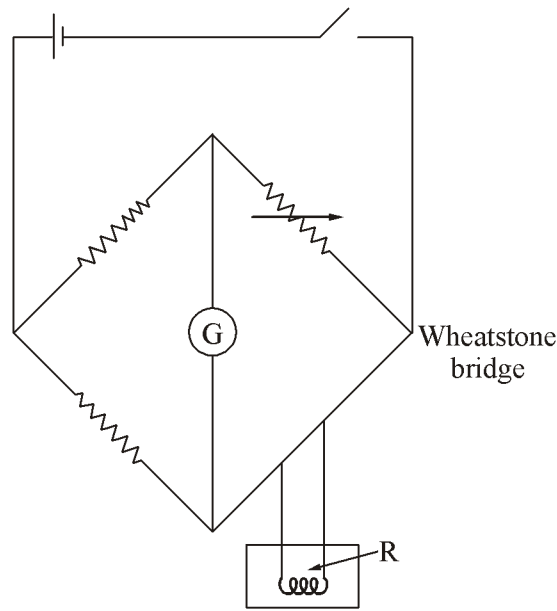
$$T = \phi(p)$$

P = It is the property of the system

## 1.13 TYPE OF THERMOMETERS

### 1.13.1 ELECTRICAL RESISTANCE THERMOMETER

In resistance thermometer shown in figure the change in resistance of metal wire due to its change in temperature is the thermometric property. The wire, frequently platinum, may be incorporated in a wheat stone bridge circuit. The platinum resistance thermometer measure temperature to a high degree of accuracy and sensitivity, which make it suitable as a standard for the calibration of other thermometers. In a restricted rang. The following quadratic equation is often used



*Resistance Thermometer*

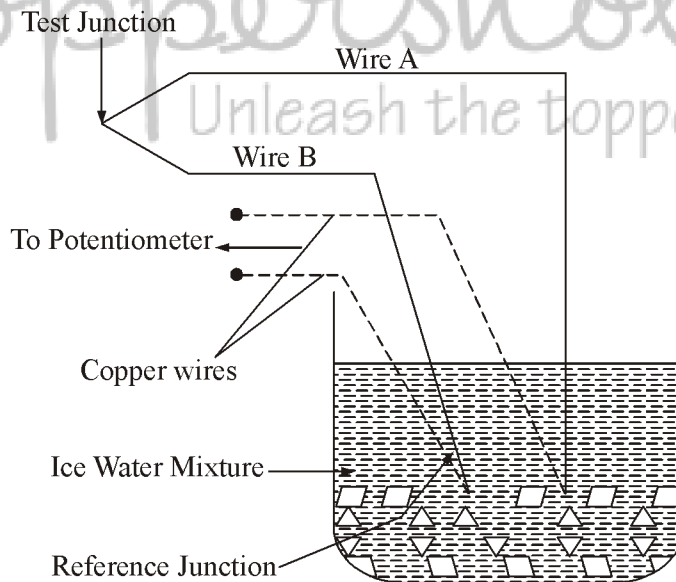
$$\frac{P}{Q} = \frac{R}{S}$$

$$R = R_0(1 + \alpha t + \beta t^2)$$

Where,  $R_0$  is the resistance of the platinum wire. When it is surrounded by melting ice and  $A$  and  $B$  are constant.

**1.13.2 THERMOCOUPLE**

A thermocouple circuit made up from joining two wire  $A$  and  $B$  made of dissimilar metals is shown in figure.



*Thermocouple*

Due to seeback effect, a net e.m.f. is generated in circuit which depends on the difference in temperature between the hot and cold junction and is, therefore a thermometric property of the circuit the e.m.f. can be measured by a microvoltmeter to a high degree of accuracy.

The choice of metals depends largely on the temperature range to be investigated and copper-constantan, chromel-alumel and platinum-platinum-rhodium are typical combinations in used.

A thermocouple is calibrated by measuring the thermal e.m.f. at various known temperature, the reference junction being kept at 0°C. The results of such measurement on most thermocouple can usually be represented by a cubic equation of the form

$$\varepsilon = a + bt + ct^2 + dt^3$$

Where,  $\varepsilon$  is the thermal e.m.f. and the constants  $a$ ,  $b$ ,  $c$ , and  $d$  are different from each thermocouple.

The advantage of the thermocouple is that of it comes to thermal equilibriums with the system. Whose temperature is to be measure, quite rapidly, because its mass is small.

### 1.13.3 CONSTANT VOLUME GAS THERMOMETER

In constant volume gas thermometer pressure is thermometric property

### 1.13.4 CONSTANT PRESSURE GAS THERMOMETER

In these volume plays the role of thermometric property.

### 1.13.5 INTERNATIONAL PRACTICAL TEMPERATURE SCALE

An international temperature scale was adopted at the Seventh General conference on weight and measures held in 1927.

TEMPERATURE OF FIXED POINT		
	Fixed Point	Temperature °C
(i)	Normal boiling point of Oxygen	-182.97
(ii)	Triple point of water (Standard)	+0.01
(iii)	Normal boiling point of Water	100.00
(iv)	Normal boiling point of Sulphur	444.60
(v)	Normal melting point of zinc-suggested as an alternative to the sulphur point	419.50
(vi)	Normal melting point of Antimony	630.50
(vii)	Normal melting point of Silver	960.80
(viii)	Normal melting point of Gold	1063.00

#### (1) From 0 to 660°C

A platinum resistance thermometer with platinum wire whose diameter must lie between 0.05 to 0.20 mm is used and the temperature is given by the equation

$$R = R_0(1 + At + Bt^2)$$

Where,  $R_0$ ,  $A$  and  $B$  are computed by measurement at ice point, steam point and sulphur point.

#### (2) From -190 to 0°C

The same platinum resistance thermometer is used and the temperature is given by

$$R = R_0(1 + At + Bt^2 + C(t - 100)t^3)$$

Where,  $R_0$ ,  $A$  and  $B$  are the same before, and  $C$  is determined from a measurement of the oxygen point.

## (3) From 660 to 1063°C

A thermocouple, one wire of which is made of platinum and the other of an alloy of 90% platinum and 10% rhodium is used with one junction at 0°C. The temperature is given by the formula

Where, a, b, and c are computed from measurement at the antimony point, Silver point and gold point. The diameter of each wire of the thermocouple must lie between 0.35 to 0.65 mm.

**1.14 METHOD USED BEFORE 1954 FOR FINDING TEMPERATURE**

The thermometer is first placed in contact with the system whose temperature  $T(x)$  is to be measured and then in contact with an arbitrarily chosen standard system in an easily reproducible state where the temperature is  $T_1$  thus assume linear relation between temperature and thermometric property.

$$t = ap + b$$

Where,

$$p = \text{Thermometric property}$$

At first reference point

$$t = t_1$$

$$P = P_1$$

$$t_1 = aP_1 + b \quad \dots(1)$$

Then the thermometer at the  $T(x)$  is placed in contact with another arbitrarily chosen standard system in another easily reproducible state where the temperature is  $T_2$  is given at second reference point

$$t = t_2$$

$$P = P_2$$

$$t_2 = aP_2 + b \quad \dots(2)$$

Solving equation (1) and (2)

$$t_1 = aP_1 + b$$

$$t_2 = aP_2 + b$$

$$t_1 - t_2 = a(P_1 - P_2)$$

$$a = \frac{t_1 - t_2}{P_1 - P_2}$$

Put value in equation (1)

$$t_1 = \left( \frac{t_1 - t_2}{P_1 - P_2} \right) P_1 + b$$

Then

$$b = t_1 - \left( \frac{t_1 - t_2}{P_1 - P_2} \right) P_1$$

Put value of a and b in equation

$$t = aP + b$$

$$t = \left( \frac{t_1 - t_2}{P_1 - P_2} \right) P + t_1 - \left( \frac{t_1 - t_2}{P_1 - P_2} \right) P_1$$

$$t - t_1 = \left( \frac{t_1 - t_2}{P_1 - P_2} \right) (P - P_1)$$

$$\boxed{\frac{t - t_1}{t_1 - t_2} = \frac{P - P_1}{P_1 - P_2}}$$

From these relation we can find temperature at any given value of 'P'.

**Before 1954, there were two fixed points**

- (i) The ice point, the temperature at which pure ice coexisted in equilibrium with air saturated water at one atmospheric pressure
  - (ii) The steam point, the temperature of equilibrium between pure water and pure steam at one atmospheric pressure
- temperature interval, between these two fixed points was chosen to be 100 degree.

The use of two fixed points was found unsatisfactory and later abandoned because of (a) The difficulty of achieving equilibrium between pure ice and air saturated water (Since when ice melts, it surrounds itself only with pure water and prevent intimate contact with air saturated water) and (b) extreme sensitiveness of the steam point to change in pressure.

### 1.15 METHOD USED AFTER 1954 FOR FINDING TEMPERATURE

Since 1954 only one fixed point has been in use. The triple point of water. The state at which ice, liquid water and water vapour coexist in equilibrium. The temperature at which this state exists is arbitrarily assigned the value 273.16 degree Kelvin, or 273.16 k. Designating the triple point of water by  $T_{tp}$  and with  $P_{tp}$  being the value of the thermometric property when the body whose temperature  $t$  is to be measured is placed in contact with water at triple point, it follows that

$$t = a P \quad \dots(1)$$

$$t_{tp} = a P_{tp}$$

$$a = \frac{t_{tp}}{P_{tp}}$$

Put value of  $a$  in equation (1)

$$t = \frac{t_{tp}}{P_{tp}} P$$

$$t = 273.16 \frac{P}{P_{tp}}$$

The temperature of the triple point of water which is an easily reproducible state, is now the standard fixed point of thermometer.

#### Comparison of Thermometers

Applying the above principle to the five thermometers listed below the temperature given as

- (i) Constant volume gas thermometer

$$t = 273.16 \frac{P}{P_{tp}}$$

- (ii) Constant pressure gas thermometer

$$t = 273.16 \frac{V}{V_{tp}}$$

- (iii) Electric resistance thermometer

$$t = 273.16 \frac{R}{R_{tp}}$$

(iv) Thermocouple

$$t = 273.16 \frac{\varepsilon}{\varepsilon_{tp}}$$

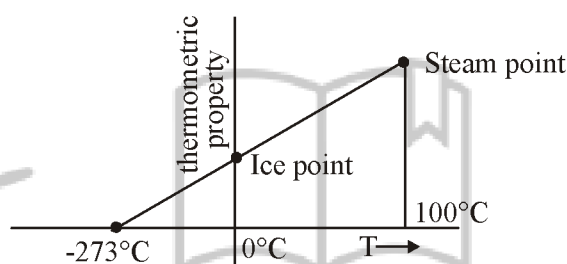
(e) Liquid -in-glass thermometer

$$t = 273.16 \frac{L}{L_{tp}}$$

**Note:** (i) If the temperature of a given system is measured simultaneously with each of five thermometers, it is found that there is considerable difference among the readings. The smallest variation is however, observed among different gas thermometers. That's why a gas is chosen as the standard thermometric substance.

(ii) The triple point of water taken as 273.16 K (0.01°C)

(iii) We assume temperature varies linearly with thermometric property and find the coefficient  $a'$  and  $b'$  with respect to these variations by fixing arbitrary points Ice point and Steam point and assume temperature respectively 0°C and 100°C



- Then we find lowest temperature with these variations can be  $-273.15^\circ\text{C}$ .
- Temperature scale arbitrary taken.

**Example:** A platinum resistance thermometer has a resistance of  $2.8 \Omega$  at  $0^\circ\text{C}$  and  $3.8 \Omega$  at  $100^\circ\text{C}$ . Calculate the temperature when the resistance indicated is  $5.8 \Omega$ .

**Solution:** Let

$$R = R_0(1 + \alpha t)$$

Where

$R_0$  = the resistance at  $0^\circ\text{C}$ .

Therefore,

$$R_0 = 2.8 \Omega$$

$$R_{100} = 3.8 \Omega$$

$$= 2.8(1 + \alpha \times 100)$$

$\therefore$

$$\alpha = \left( \frac{3.8}{2.8} - 1 \right) \times 10^{-2}$$

$$= 0.357 \times 10^{-2}$$

When

$$R = 5.8 \Omega$$

$$5.8 = 2.8(1 + 0.357 \times 10^{-2} t)$$

$\Rightarrow$

$$t = \left( \frac{5.8}{2.8} - 1 \right) \times \left( \frac{100}{0.357} \right) = 300^\circ\text{C}$$

**Example:** A temperature scale of certain thermometer is given by the relation  $t = a \ln p + b$  where  $a$  and  $b$  are constants and  $p$  is the thermometric property of the fluid in the thermometer. If at the ice point and steam point the thermometric properties are found to be 1.5 and 7.5 respectively what will be the temperature corresponding to the thermometric property of 3.5 on Celsius scale.

**Solution:** On Celsius scale  $t = a \ln p + b$

$$\text{Ice point} = 0^\circ\text{C}$$

$$\text{and Steam point} = 100^\circ\text{C}$$

$\therefore$  From given conditions, we have

$$0 = a \ln 1.5 + b \quad \dots(1)$$

$$\text{and } 100 = a \ln 7.5 + b \quad \dots(2)$$

$$\text{i.e., } 0 = a \times 0.4054 + b \quad \dots(3)$$

$$\text{and } 100 = a \times 2.015 + b \quad \dots(4)$$

Subtracting (3) from (4), we get

$$100 = 1.61a$$

$$\text{or } a = 62.112$$

Substituting this value in equation (3), we get

$$\begin{aligned} b &= -0.4054 \times 62.112 \\ &= -25.18 \end{aligned}$$

$\therefore$  When  $P = 3.5$  the value of temperature is given by

$$\begin{aligned} t &= 62.112 \ln(3.5) - 25.18 \\ &= 52.63^\circ\text{C} \end{aligned}$$

**Example:** In a New temperature ( $^\circ\text{N}$ ) scale the boiling and freezing point are  $400^\circ\text{N}$  and  $100^\circ\text{N}$  respectively. What will be the reading on new scale. Corresponding to  $60^\circ\text{C}$ .

**Solution :** Take  $^\circ\text{N} = a \times ^\circ\text{C} + b \quad \dots(1)$

$$\Rightarrow 400 = a \times 100 + b$$

$$\Rightarrow 100 = a \times (0) + b$$

$$\Rightarrow 300 = a \times 100$$

$$\Rightarrow a = 3$$

$$\Rightarrow 100 = a \times (0) + b$$

$$\Rightarrow b = 100$$

$$\text{From equation (1)} \quad ^\circ\text{N} = 3^\circ\text{C} + 100$$

at  $60^\circ\text{C}$

$$\Rightarrow ^\circ\text{N} = 3 \times 60 + 100$$

$$\Rightarrow ^\circ\text{N} = 280^\circ$$

**Example:** A thermocouple with test junction at  $t^\circ\text{C}$  on gas thermometer scale and reference junction at ice point gives the e.m.f. as  $e = 0.20t - 5 \times 10^{-4}t^2$  mV. The millivoltmeter is calibrated at ice and steam points. What will be the reading on this thermometer where the gas thermometer reads  $70^\circ\text{C}$ ?

*Solution :*

At ice point, when

$$e = 0.20t - 5 \times 10^{-4}t^2 \text{ mV}$$

$$t = 0^\circ\text{C}, e = 0$$

At steam point, when

$$t = 100^\circ\text{C}$$

$$e = 0.20 \times 100 - 5 \times 10^{-4} \times (100)^2$$

$$= 15 \text{ mV}$$

Now, when

$$t = 70^\circ\text{C}$$

$$e = 0.20 \times 70 - 5 \times 10^{-4} \times (70)^2$$

$$= 11.55 \text{ mV}$$

$\therefore$  When the gas thermometer reads  $70^\circ\text{C}$  the thermocouple will read

$$t = \frac{100 \times 11.55}{15}$$

$$t = 77^\circ\text{C}$$

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# PRACTICE SHEET

## OBJECTIVE QUESTIONS

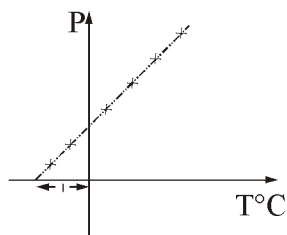
1. The study of thermodynamics provides answer to the following
- |   | <b>Codes: A</b> | <b>B</b> | <b>C</b> | <b>D</b> |
|---|-----------------|----------|----------|----------|
| 1. whether a process is feasible or not           | (a) 4           | 2        | 1        | 3        |
| 2. to quantify the energy required for a process  | (b) 1           | 4        | 3        | 2        |
| 3. rate or speed with which a process occurs      | (c) 1           | 3        | 4        | 2        |
| 4. extent to which a reaction/process takes place | (d) 3           | 1        | 2        | 4        |
5. Match the following List-I (Thermometer) with List-II (Thermometric property)
- |  | <b>List-I</b>                   | <b>List-II</b>     |
|--|---------------------------------|--------------------|
|  | <b>A.</b> Mercury-in-glass gas  | <b>1.</b> Volume   |
|  | <b>B.</b> Constant pressure gas | <b>2.</b> Length   |
|  | <b>C.</b> Constant volume gas   | <b>3.</b> EMF      |
|  | <b>D.</b> Thermocouple          | <b>4.</b> Pressure |
- Which of the above is/are correct?
- |                |                |
|----------------|----------------|
| (a) 1, 2 and 3 | (b) 1 and 2    |
| (c) 1, 2 and 4 | (d) 2, 3 and 4 |
2. Consider the following statements
1. Thermodynamic properties are the macroscopic coordinates significant only for systems existing in states of thermodynamic equilibrium.
  2. Engineering thermodynamic studies about storage, transfer and transformation of energy.
- Which of the above is/are correct?
- |            |                   |
|------------|-------------------|
| (a) 1 only | (b) 1 and 2       |
| (c) 2 only | (d) None of these |
3. An adiabatic boundary is one which
- (a) prevents heat transfer
  - (b) permits heat transfer
  - (c) prevents work transfer
  - (d) permits work transfer
4. Match the following List-I with List-II
- | <b>List-I</b>                  |  |
|--------------------------------|--|
| <b>A.</b> Centrifugal fan      |  |
| <b>B.</b> Control volume       |  |
| <b>C.</b> Intensive property   |  |
| <b>D.</b> Microscopic property |  |
- | <b>List-II</b>                          |  |
|---|--|
| <b>1.</b> Open system                   |  |
| <b>2.</b> Internal energy               |  |
| <b>3.</b> Filling a tire at air station |  |
| <b>4.</b> Specific energy               |  |
6. In a quasiequilibrium process, the pressure in a system
- (a) remains constant
  - (b) varies with temperature
  - (c) is everywhere constant at an instant
  - (d) increase if volume increases
7. Convert the following readings of pressure to kPa, assuming that the barometer reads 760 mm of Hg and match the List-I with List-II.
- | <b>List-I</b>                            | <b>List-II</b>      |
|--|---------------------|
| <b>A.</b> 50 cm Hg vacuum                | <b>1.</b> 113 kPa   |
| <b>B.</b> 80 cm Hg gauge                 | <b>2.</b> 34.65 kPa |
| <b>C.</b> 1.2m of H <sub>2</sub> O gauge | <b>3.</b> 209 kPa   |
- | <b>Codes: A</b> | <b>B</b> | <b>C</b> |
|-----------------|----------|----------|
| (a) 1           | 3        | 2        |
| (b) 1           | 2        | 3        |
| (c) 2           | 3        | 1        |
| (d) 3           | 1        | 2        |

8. Match the List-I (Terms) with List-II (Description) and select the correct answer:
- | List-I             | List-II                               |
|--------------------|---------------------------------------|
| A. Change of state | 1. Succession of states               |
| B. Path            | 2. One or more properties changes     |
| C. Process         | 3. Change of state for specified path |
- Codes:**    **A**        **B**        **C**
- (a) 2        1        3  
 (b) 1        3        2  
 (c) 2        3        1  
 (d) 3        1        2
9. For an isolated system executing a process
1. no heat transfer takes place
  2. no work is done
  3. no mass crosses the boundary
  4. no chemical reaction takes place within the system
- Which of the above statement are correct?
- (a) 1, 2 and 3        (b) 1, 3 and 4  
 (c) 2, 3 and 4        (d) All of the above
10. Which of the following aspect is not true regarding microscopic properties of thermodynamic system?
- (a) A knowledge of the structure of matter is essential.
  - (b) A limited number of variables/properties are needed to describe the state of matter.
  - (c) The values of these variables cannot be measured.
  - (d) Statistical averaging is adopted to predict the behavior of individual fluid particles.
11. Choose the correct statement among the following:
- (a) temperature is an extensive property
  - (b) mass remains same in an open system
  - (c) the system boundaries are collapsible and expandable
  - (d) an isolated system allows exchange of energy in the form of heat only
12. Which of the following is an example of heterogeneous system?
- (a) Atmospheric air
  - (b) mixture of hydrogen and oxygen
  - (c) Cooling fluid in a radiator
  - (d) Mixture of ice, water and steam
13. The sequence of processes that eventually returns the working substance to its original state is known as
- (a) event
  - (b) process
  - (c) thermodynamic property
  - (d) thermodynamic cycle
14. A system and its environment put together form universe called as
- (a) an adiabatic system
  - (b) an isolated system
  - (c) a segregated system
  - (d) a homogeneous system
15. Which one of the following is extensive property of a thermodynamics system
- (a) Volume        (b) Pressure
  - (c) Temperature        (d) Density
16. Which of the following quantities is not the property of the system
- (a) Pressure        (b) Temperature
  - (c) Density        (d) Heat
17. The fundamental unit of enthalpy is
- (a)  $MLT^{-2}$         (b)  $ML^3T^{-1}$
  - (c)  $ML^2T^{-2}$         (d)  $ML^3T^{-2}$
18. A closed thermodynamic system is one in which
- (a) there is no energy or mass transfer across the boundary
  - (b) there is no mass transfer, but energy transfer exists
  - (c) there is no energy transfer, but mass transfer exists
  - (d) both energy and mass transfer takes place across the boundary but the mass transfer is controlled by valves

19. The value of an extensive property is extensively dependent on
- mass or extend of the system
  - interaction of the system with its surroundings
  - path followed by the system in going from one state to another
  - nature of boundaries, rigid or flexible
20. A diathermic wall is one which
- prevents thermal interaction
  - permits thermal interaction
  - encourages thermal interaction
  - discourages thermal interaction
21. Which of the following are intensive properties
- Kinetic energy
  - Specific enthalpy
  - Pressure
  - Entropy
- 1 and 3
  - 2 and 3
  - 1, 3 and 4
  - 2 and 4
22. For a system to be in thermodynamic equilibrium the system and its surroundings are to be in
- Thermal equilibrium
  - Chemical equilibrium
  - Mechanical equilibrium
  - Thermal, chemical and mechanical equilibrium
23. Which of the following statements regarding the concept of continuum are correct?
- Large number of molecules enable meaningful statistical average and assignment of property values
  - Mean free path of the molecules is order of magnitude higher than system dimensions
  - Behaviour of individual molecules is disregarded
  - Mean free path of the molecules approaches the order on magnitude of the system dimensions
- 1 and 3
  - 2 and 3
  - 3 and 4
  - 1 and 4
24. State of pure substance can be fixed by specifying
- one property
  - Two properties
  - three properties
  - none of these
25. Zeroth of thermodynamics states that:
- two thermodynamic systems are always in thermal equilibrium with each other.
  - if two systems are in thermal equilibrium with a third system are also not in thermal equilibrium with each other.
  - two systems not in thermal equilibrium with a third system are also not in thermal equilibrium with each other.
  - when two systems are in thermal equilibrium with a third system, they are in thermal equilibrium with each other.
26. The Kelvin temperature of a system can be measured by a
- mercury-in-glass thermometer
  - thermocouple
  - constant-volume gas thermometer
  - resistance thermometer
27. As per international practice, the temperature interval from oxygen point to gold point is divided into three main parts. Which of the following temperature interval is not correct?
- 0 to 560°C
  - 0 to 660°C
  - 190°C to 0°C
  - 660 to 1093°C
28. Match List-I with List-II the following:
- List-I**
- Normal boiling point of oxygen
  - Triple point of water
  - Normal boiling point of water
  - Normal melting point of gold
- List-II**
- 100°C
  - 183°C
  - 1063°C
  - 0.01°C

5.  $0.001^{\circ}\text{C}$ 

- Codes: A B C D**
- (a) 2 5 3 1  
 (b) 2 4 1 3  
 (c) 2 5 1 3  
 (d) 3 4 1 2
29. Which of the following is used for measuring high temperature beyond  $1063^{\circ}\text{C}$ ?  
 (a) Platinum-platinum/Rhodium thermocouple  
 (b) Electrical resistance thermometer  
 (c) Optical method using Planck's law of thermal radiation (pyrometer)  
 (d) Constant pressure gas thermometer
30. Zeroth law of thermodynamics forms the basis of measurement of  
 (a) pressure (b) temperature  
 (c) heat exchanger (d) work
31. The standard fixed point of thermometry is  
 (a) ice point  
 (b) Sulphur point  
 (c) Triple point of water  
 (d) Normal boiling point of water
32. Triple point temperature of water is  
 (a) 273 K (b) 273.14 K  
 (c) 273.15 K (d) 273.16 K
33. Experimental data obtained from a constant-volume-gas thermometer is shown in the figure below. The value in  $^{\circ}\text{C}$  is



- (a) 273.15 (b) 1.0  
 (c) -100 (d) -273.15

34. In a new temperature scale say  $^{\circ}\text{P}$  the boiling and freezing points of water at one atmosphere are  $100^{\circ}\text{P}$  and  $300^{\circ}\text{P}$  respectively, correlate this scale with the centigrade scale. The reading of  $0^{\circ}\text{P}$  on the centigrade scale is  
 (a)  $0^{\circ}\text{C}$  (b)  $50^{\circ}\text{C}$

(c)  $100^{\circ}\text{C}$  (d)  $150^{\circ}\text{C}$ 

35. Two blocks which are at different states are brought into contact with each other and allowed to reach a final state of thermal equilibrium. The temperature is specified by the  
 (a) Zeroth law of thermodynamics  
 (b) First law of thermodynamics  
 (c) Second law of thermodynamics  
 (d) Third law of thermodynamics
36. Which thermometer is independent of the substance or material used in its construction?  
 (a) Mercury thermometer  
 (b) Alcohol thermometer  
 (c) Ideal gas thermometer  
 (d) Resistance thermometer
37. A system is partitioned into two equal parts. An intensive property of each part will  
 (a) become half  
 (b) remain unchanged  
 (c) double  
 (d) depend upon the nature of the intensive property
38. For  $\text{NH}_3 - \text{CH}_4$  mixture system existing in two phases in equilibrium. The number of independent properties required to fix the state of the system are  
 (a) 1 (b) 2  
 (c) 3 (d) 4
39. For a mixture of solid, liquid, and vapour phases of a pure substance in equilibrium, what is the number of independent intensive properties needed?  
 (a) 0 (b) 1  
 (c) 2 (d) 3
40. A platinum wire is used as a resistance thermometer. The wire resistance was found to be 20 ohm and 36 ohm at the ice point and steam point respectively and 40 ohm at the melting point of antimony  $630.50^{\circ}\text{C}$ . Find the resistance of the wire at  $700^{\circ}\text{C}$ . If the resistance varies with temperature by the relation  $R = R_0(1 + at + bt^2)$   
 (a) 31.2 ohm (b) 169.540 ohm  
 (c) 303.540 ohm (d) 144.390 ohm

## ANSWERS AND EXPLANATIONS

1. *Ans.(c)*2. *Ans.(b)*3. *Ans.(a)*4. *Ans.(c)*5. *Ans.(d)*

Mercury-in-glass : Length

Radiation : Black body radiation

Thermocouple : EMF

Constant volume gas : Pressure

Constant pressure gas : Volume

6. *Ans.(c)*7. *Ans.(c)***50 cm Hg vacume :**

$$\begin{aligned} P_{\text{vacuum}} &= \rho gh \\ &= 13.6 \times 10^3 \times 9.8 \times 50 \times 10^{-2} \\ &= 66.64 \text{ kPa} \end{aligned}$$

$$\begin{aligned} P_{\text{abs}} &= P_{\text{atm}} - P_{\text{vac}} \\ &= (760 - 500) \times 9.8 \times 13.6 \\ &= 34.65 \text{ kPa} \end{aligned}$$

**80 cm Hg gauge :**

$$\begin{aligned} P_{\text{abs}} &= P_{\text{atm}} + P_{\text{gauge}} \\ &= (760 + 800) \times 9.8 \times 13.6 \\ &= 209 \text{ kPa} \end{aligned}$$

**1.2 m of H<sub>2</sub>O guage :**

$$\begin{aligned} P_{\text{abs}} &= P_{\text{atm}} + P_{\text{guage}} \\ &= 101.325 + 1.2 \times 9.8 \\ &= 113 \text{ kPa} \end{aligned}$$

8. *Ans.(a)*

Properties are the coordinated to describe the state of a system. They are state variables of the system. Any operation in which one or more of the properties of a system change is called a change of state. The succession of states passes through during a change of state is called the path of the change of state is called a process. A thermodynamic cycle is defined as a series of state changes such that the final state is identical with the initial state.

9. *Ans.(a)*10. *Ans.(b)*11. *Ans.(d)*12. *Ans.(d)*

**Homogeneous thermodynamic system** is defined as the one whose chemical composition and physical properties are the same in all part of the system, or change continuously from one point to another *example* imagine a column of atmospheric air mainly nitrogen and oxygen. In a system of this kind, acted upon by the force of gravity, both the composition of the system and its physical properties will continuously change from one point to another.

**Heterogeneous thermodynamic system** is defined as one consisting of two or more homogeneous bodies. The homogeneous bodies of a heterogeneous system are referred to as phase. Each phase is separated from other phases by interface. *Example* mixture of water, ice and vapour etc.

13. *Ans.(d)*

Thermodynamic cycle can be defined as a series of state changes such that the final and initial state is identical.

14. *Ans.(b)*

An isolated system is one in which there is no interaction of system with the surrounding.

for isolated system

$$dQ = 0$$

$$dW = 0$$

The first law gives

$$dQ = du + dW$$

$$du = 0$$

$$u = \text{constant}$$

The energy of isolated system is constant

15. *Ans.(a)*

Since volume depends on mass hence it is extensive property

16. *Ans.(d)*

Since heat transfer is the path function hence it is not the property of the system.

17. *Ans.(c)*  
 Unit is joule and for joule  
 $= F \times x = m^1L^1T^{-2} \times L^1 = M^1L^2T^{-2}$

18. *Ans.(b)*  
**Open system :**  
 Both mass and energy transfer takes place  
**Closed system :**  
 No mass transfer, energy transfer takes place

19. *Ans.(a)*

20. *Ans.(b)*

21. *Ans.(b)*  
 Specific enthalpy (enthalpy per unit mass) and pressure is intensive property.

22. *Ans.(d)*

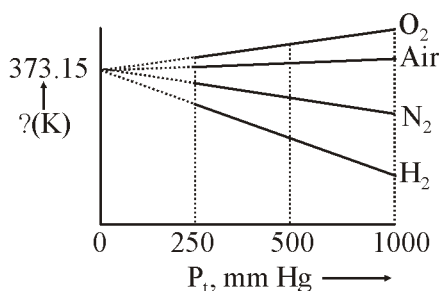
23. *Ans.(c)*

**Concept of Continuum** is a kind of idealization of the continuous description of matter where the properties of matter are considered as continuous function of space variables. Although any matter is composed of several molecules, the concept of continuum assumes a continuous distribution of mass within the matter or system with no empty space, instead of actual conglomeration of separate molecules (a thing consisting of number of differens distint parts or item and that are grouped together it is meaning of conglomeration) for follow continuum concept characteristic length of molecular system should be more than mean free path (distance between two collisons) characteristic length is diameter of molecule  $\lambda < D$  (follow continuum concept)

24. *Ans.(b)*

25. *Ans.(d)*

26. *Ans.(c)*



27. *Ans.(a)*

28. *Ans.(b)*

29. *Ans.(c)*  
 0 – 660°C → Platinum resistance thermocouple  
 – 190 to 0°C → platinum-platinum/Rhodium thermocouple  
 > 1063°C → Planck's law of thermal radiation.

30. *Ans.(b)*

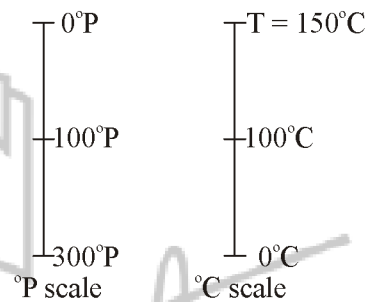
Zeroth law — concept of temperature  
 First law — concept of internal energy  
 Secondary law — concept of entropy

31. *Ans.(c)*

32. *Ans.(d)*

33. *Ans.(d)*

34. *Ans.(d)*



$$\frac{100 - 300}{0 - 300} = \frac{100 - 0}{T - 0}$$

$$T = 100 \times \frac{-300}{-200}$$

$$T = 150^\circ\text{C}$$

35. *Ans.(a)*

36. *Ans.(c)*

37. *Ans.(b)*

An intensive property is not depended on mass of the system.

38. *Ans.(b)*

We know that

$$P + F = C + 2$$

$$2 + F = 2 + 2$$

$$F = 2$$

So 2 properties required.

39. *Ans.(a)*

We know that

$$P + F = C + 2$$

$$3 + F = 1 + 2$$

$$F = 0$$

40. *Ans.(a)*

$$R = R_0(1 + at + bt^2)$$

At ice point

$$t = 0$$

$$20 = R_0(1 + a \times 0 + b \times 0)$$

$$R_0 = 20$$

At steam point

$$t = 100^\circ\text{C}$$

$$36 = 20[1 + 100a + 10^4b]$$

$$1 + 100a + 10^4b = 1.8$$

$$100a + 10000b = 0.8$$

$$a = \frac{0.8 - 10000b}{100}$$

at

$$t = 630.5^\circ\text{C}$$

$$40 = 20[1 + 630.5a + (630.5)^2b]$$

$$2 = 1 + \frac{630.5}{100}[0.8 - 10^4b] + (630.5)^2b$$

$$1 = 5.04 - 63050b + 397530.25b$$

$$b = -1.2 \times 10^{-5}$$

$$a = 9.2 \times 10^{-3}$$

So at  $700^\circ\text{C}$ 

$$R = 20[1 + 9.2 \times 10^{-3} \times 700 - 1.2 \times 10^{-5}(700)^2]$$

$$= 31.2 \text{ ohm}$$

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