1
Engineering Thermodynamics

Q.1. What is System as applied to Thermodynamics ?

Ans. Whenever a change is to be analyzed it is necessary to specify the region under study in order to avoid any confusion, In thermodynamics this is done by drawing a boundary around the region of consideration. This boundary may be real or imaginary, moreover, it may be fixed or it may change in shape as well as volume Everything within the boundary is called the system, while the region external to the boundary is called the surroundings.

The system is a specified region wherein changes due to transfers of mass or energy or both are to be studied. It is not necessary that the volume or shape of the system should remain fixed.

Q.2. What do you understand by closed System? Open System? Isolated System?

Ans. If mass within the boundary of the system remains constant, it is called a closed system. Thus a closed system does not permit any mass transfer across its boundary but it permits transfer of energy.

If both mass and energy cross the boundary of a system it is called open system. Thus an open system permits both mass and energy transfer across the boundaries, and the mass within the system may not be constant.

If neither mass nor energy are allowed to cross the boundary of a system it is called an Isolated System. Thus an isolated system does not have transfer of either mass or energy with the surroundings.

Q. 3. What is thermodynamic property? What is intensive and extensive property?

Ans. A thermodynamic system would have many characteristics, directly or indirectly measurable, which would serve to describe or identify the system. For example, mass, temperature, pressure, volume, velocity, elevation and electrical potential are such characteristics. In addition, a large number of other characteristics of the system can be defined. These characteristics or quantities, the values of which describe the system, are called thermodynamic properties.

If the value of a property is independent of the mass of the system, it is called an intensive property. Thus pressure, temperature, density, velocity, height, viscosity, etc. are intensive properties.

If the value of a property is proportional to the mass of system, it is called an extensive property. The volume, surface area, energies of all kinds, electric charge, magnetization are examples of extensive properties.

Q.4. What do you mean by Thermodynamic Equilibrium?

Ans. Thermodynamic Equilibrium means that the system is incapable of spontaneous change when it is isolated.

Thermodynamic equilibrium means complete equilibrium, *i.e.* thermal equilibrium, (uniformity of temperature or absence of temperature gradient) mechanical equilibrium (uniformity of pressure or absence of unbalance of forces), electrical equilibrium (equality of /electrical potential) and reaction equilibrium (absence of phase or change of chemical reaction).

Q.5. What is state as applied to thermodynamics?

Ans. Each unique condition of system is called a state. Thus state is the condition of a system at an instant of time as described by its properties.

Q, 6. What is process? Reversible process? Irreversible process?

Ans. When in a system undergoes a change from one equilibrium state to another it does so by means of a process. A process also occurs when a system undergoes an energy transfer at a steady state.

If a system passes through a continuous series of equilibrium states during a process, these states can be located on a diagram of

appropriate properties, and a line representing the path of process can be drawn through all the points. Such process is called a reversible process.

If a system passes through a sequence of non-equilibrium states during a process, these states cannot be located on any property diagram because each property does not have a unique value in the entire system. Such a process is called an irreversible process.

Q. 7. What is Zeroth Law of Thermodynamics?

Ans. It states that if two systems are each in thermal equalibrium with a third system, then the two systems are in thermal equilibrium with each other.

Q. 8. What is First Law of Thermodynamics?

Ans. The First Law may be stated in the following ways:

1. If the system is carried through a cycle (the end state being precisely the same as the initial stage) then summation of the work delivered to the surroundings is proportional to the summation of the heat taken from the surroundings.
2. Heat and work are mutually convertible, but since energy can neither be created nor destroyed, the total energy associated with an energy conservation, remains constant.
3. No machine can produce energy without corresponding expenditure of energy i.e. it is impossible to construct a perpetual motion machine of the first kind.

Q. 9. What is Second Law of Thermodynamics?

Ans. It states that all forms of energy are not equivalent in their ability to do work. It declares that certain processes are impossible to perform even though these processes do not violate the First Law.

For example, the First Law states in every cyclic process either work is converted into heat or heat is converted into work. The Second Law, on the other hand, makes the distinction between these two quantities by stating that heat from a single source whose temperature is uniform cannot be completely converted into work in any cyclic process.

Q. 10. What is Clasius Statements of the Second Law?

Ans. (*i*) No process is possible whose sole effect is the removal of heat from a reservoir at one temperature and the absorption of an equal amount of heat by a reservoir at a higher temperature.

or

(*ii*) It is impossible to construct a device which, operating in a cycle, will produce no effect other than the transference of heat, from a colder to a hotter body.

or

(*iii*) Heat cannot, of itself, flow from a lower to a higher temperature.

Q.11. What is Kelvin-Planck Statement of Second Law?

Ans. (*i*) No process is possible whose sole effect is removal of heat from a single reservoir and the performance of an equivalent amount of work.

Or

(*ii*) It is impossible to construct a device, which, operating in a cycle, will produce no effect except raising of a weight and the cooling of a heat reservoir.

Q. 12. What is throttling process?

Ans. This is a process in which a fluid undergoes an expansion from a high pressure to a lower pressure with no heat transfer, no work transfer, and no change in kinetic or potential energy. In this process initial and final enthalpies are equal.

Q.13. What is heat?

Ans. It is a form of energy due to molecular motion. The molecules of any substance containing heat are assumed to be constantly in motion, and the intensity (or temperature) of heat, depends upon the rapidity of this molecular vibration. The temperature of a body will rise as the rate of vibration increases, and falls as it decreases. To understand this fully, just consider that at absolute zero (– 273°C), there is no molecular action, therefore, no-heat. That means anything above absolute zero has its molecules in constant motion.

Q.14. What are the effects of adding heat to a body ?

Ans. Addition of heat to a body may cause (*i*) rise in temperature ; (*ii*) change of state—for example, from solid to liquid (ice to water) or liquid to gas (water to steam) ; (*iii*) performance of external work by expansion of the solid, liquid or gaseous body to' which the heat is added.

All the foregoing effects are seen if heat is applied to ice to melt it into water, thus changing its, state without raising its temperature; if addition of heat is continued until the water reaches the

boiling point, thus raising its temperature without changing its-state, finally, if heat is added until the water turns into steam, which is another change of state without a rise in temperature.

As steam is generated, it exerts pressure on the walls of the vessel in which it is confined. If this vessel is a cylinder containing: a movable piston, the steam can do external work by moving the piston.

Q.15. How is heat transferred from one body to another?

Ans. It is convenient to think of heat as flowing like a fluid from one body to another, but strictly speaking there is no transfer of any physical substance. Molecules in the hotter substance are vibrating at a higher rate than those in the colder substance; therefore, when the bodies are brought into contact, the effect is to-increase molecular vibration in the colder body and decrease vibration in the hotter body until equilibrium is established. Unless, artificially reversed by outside power (as in refrigerating machine), heat transfer is always from the hotter body.

Q. 16. What is temperature ?

Ans. It is a measure of heat intensity, or degree of hotness or coldness as distinct from quantity. A very small body and a very large one may be at exactly the same temperature, but it is obvious, that the large body contains a much greater quantity of heat than, the small body.

Q. 17. What is meant by specific heat of a substance?

Ans. It is the amount of heat required to raise the temperature of one kilogram of that substance through one degree centigrade.

Q. 18. How is heat transmitted from one body to another ?

Ans. By radiation, conduction, and convection.

Q. 19. What is radiation ?

Ans. It is giving off of heat from a hot body by either waves of the same nature as light waves. Radiant heat does not warm the air to any great extent as it passes through it, but is absorbed or reflected by any solid obstruction. In a boiler furnance we have direct heat radiation from the boiler fire to all parts of the boiler that can “see” the fire.

Q. 20. What is conduction?

Ans. It is the passage of heat through a body by the contact of one

molecule with another. For example, if one end of an iron bar is placed in a fire while the other end is held in the hand, in a short time the end in hand will become unbearably hot because of the conduction of heat through the bar from the red-hot end. Here heat is passed along by a series of collisions; fast moving hot molecules bump into and speed up the cooler, slower molecules. Heat passes in this way through the tube walls and plates of a boiler to the water on the other side.

Q. 21. What is convection?

Ans. Convection is the transfer of heat by current flow. As gases or liquids are heated by conduction through the walls of a containing vessel, they tend to expand and rise, and their place is taken by the upper colder layers of liquid or gas which, being heavier than the heated liquid or gas, tend to flow downward. In this way convection currents are set up, and the whole body of gas or liquid is gradually heated to a uniform temperature.

It is by means of convection currents that the air of a room is heated to uniform temperature by a steam radiator. Water in a steam boiler is also heated uniformly throughout by convection currents set up by upward flow of the lighter heated water in contact with the heating surface, and by the downward flow of the heavier colder water above.

Q. 22. What is thermal conductivity?

Ans. Thermal conductivity refers to the rate at which heat passes through a body. The rate varies widely for different substances, and may (but not necessarily) be stated as the number of kcal that can flow in one hour through a block of the material, one square metre in area and one centimetre thick, with 1°C difference in temperature between the opposite surfaces. Since thermal conductivity varies with temperature, density, and moisture content, tables of thermal conductivity give only very approximate values. The rate of conductivity of metals usually decreases as temperature rises, but for most other substances the rate increases as temperature rises.

Q. 23. What is Boyle's Law?

Ans. Boyle's law states that "the absolute pressure of a gas will vary inversely as the volume, if the temperature remains constant". Or conversely, "the volume will vary inversely as the absolute pressure, if the temperature remains constant".

Q. 24. What is Charle's Law?

Ans. The law states that "the absolute pressure of a gas will vary directly as the absolute temperature, if the volume remains constant".

Or

If the pressure is held constant, the volume of a given mass of gas varies directly as the absolute temperature.

Q. 25. What is the law of Gay-Lussac ?

Ans. The law states, "volume of a gas will vary directly as the absolute temperature, if the pressure remains constant". .

Q. 26. What is meant by isothermal expansion or compression ?

Ans. It is the expansion or compression of a gas at constant temperature, that is, with the temperature remaining the same during expansion or compression. This is the condition that would exist if the changes were taking place according to Boyle's Law.

Q. 27. What is adiabatic expansion or compression ?

Ans. This is expansion or compression where the temperature rises during compression and falls during expansion without any loss of heat to cylinder walls or absorption of heat from the walls. The condition is never exactly realized in practice, although it is approached fairly in some gas engines and air compressors.

Q. 28. What is Avogadro's Hypothesis ?

Ans. It states that

'Equal volumes of all gases, under identical conditions of temperature and pressure, contain the same number of molecules.

Q, 29. What is Newton's law of cooling?

Ans. This law states that the rate of cooling is proportional to the excess temperature. It applies to cooling by convection and radiation and not by radiation alone. In practice, this condition is realised when the hot body is allowed to cool in a good draught to make the loss due to radiation small as compared to that due to forced convection.

Q. 30. What is Kirchhoiff's Law ?

Ans. This states that 'At any given temperature and for radiations of the same wave length the ratio of the emissive power to the ab-

sorptive power is the same for all substances and is equal to the emissive power of a perfectly black body.

Q. 31. What is emission, and emissive power ?

Ans Every hot body emits thermal radiation from its surface, which depends upon the nature of the surface, its size and the nature of the surroundings. This is known as emission and is estimated by a quantity known as emissive power, which may be defined as the amount of radiation emitted per sq. cm. per sec. at a given temperature.

Q. 32. What is Stefan Boltzmann law ?

Ans It states that 'The total amount of heat radiated by a perfectly black body per second per unit area is directly proportional to fourth power of its absolute temperature, *i.e.*

$$R \propto T^4$$

or

$$R = \sigma T^4$$

The value of on C.G.S. units is found to be 5.67×10^{-5} erg per sq cm per sec and on M.K.S. units as 5.67×10^{-8} w m^{-2} k^{-4}.

Q. 33. What is a Nusselt Number ?

Ans Nusselt number is a convenient measure of the convective heat transfer coefficient. It is given by

$$Nu = \frac{\phi l}{k\theta}$$

where,

ϕ = Heat flux intensity (heat flow per unit area and per unit time)

l = Linear dimension of solid

k = Thermal conductivity of fluid

θ = Temperature difference between the solid surface and fluid.

Q. 34. What do you mean by thermal conductivity?

Ans. Thermal conductivity, k, is defined as the heat transmitted, per hour and per degree of temperature difference, through a cable of unit dimensions.

Q. 35. Give expressions for Reynolds Number, Prandtle Number, and Grash of Number.

Ans. Reynolds Number

$$Re = \frac{\rho v l}{\mu}$$

$$\text{Prandtle Number } Pr = \frac{\mu C_p}{k}$$

$$\text{Grashof Number } Gr = \frac{\alpha g \theta l^3}{\mu^2}$$

where

ρ = Absolute density of fluid

v = Velocity of fluid

l = Linear dimension of solid (usually the tube diameter)

μ = Absolute viscosity of fluid

C_p = Specific heat of fluid at constant pressure

k = Termal conductivity of fluid

θ = Temperature difference between solid surface and fluid

α = Coefficient of expansion of fluid.

g = Acceleration due to gravity.

Q. 36. What it a heat exchanger?

Ans. A heat exchanger is an apparatus or an equipment in which the process of heating or cooling occurs. The heat is transferred from one fluid being cooled to another fluid being heated. For example, boilers, condensers, furnaces, evaporators are all heat exchangers of some type designed for some specified purpose but primarily to transfer heat from one fluid to another.

Q. 37. What do- you mean by direct contact heat exchanger?

Ans. It is a heat exchanger in which the process of heat transfer occurs through direct contact and mixing of the hot and cold fluids. The heat transfer is usually accompanied by mass transfer. These heat exchangers are used in cases where mixing of two fluids is either harmless or desirable. Water cooling towers and jet condensors are two examples of such heat exchangers.

Q. 38. What is a regenerator ?

Ans. It is a device in which hot and cold fluids alternately flow over the surface. The heat carried by the hot fluid is accumulated in the walls of the equipment and is then transferred to the cold fluids

when it passes over the surface next.

Q. 39. What is a recuperator?

Ans. It is a heat exchanger in which both, hot and cold fluids separated from each other by a wall, flow through the exchanger at the same time. The heat transfer process consist of convection between the fluid and wall, conduction through the wall and convection between the wall and the other fluid. In case the temperature difference, between a wall and fluid is large, radiation heat exchange may also occur. Such heat exchangers are used where the cooling and cutting fluids cannot be allowed to mix. The economizer and air-pre heater of boiler plant, radiator of a motor car, evaporator of an ice plant and milk chiller of -a. pasteurising plant belong to this category.

Q. 40. Find the unbalanced force in Newtons acting on a body to produce an acceleration of 10 m/sec2 when the body has a mass of 1 kg.

Ans. According to Newton's second law of motion

$$F \propto ma$$

or

$$F = \frac{1}{g_c} ma$$

In MKS system $g_c = \dfrac{\text{kg.m}}{\text{N} \times \text{sec}^2}$

$$\therefore \quad F = \frac{1\ \text{kg} \times 10\ \text{m}}{\text{sec}^2} \times \frac{\text{N}\ \ \text{sec}^2}{\text{kg.m}}$$

$$= 10\ \text{N.} \qquad \textbf{Ans.}$$

Q.41. Are the following systems open or closed? Scooter engine, electric fan, car battery, centrifugal pump, pressure cooker, steam boiler.

Ans.

	Scooter Engine	:	Open System
	Electric fan	:	Closed System
	Car battery	:	Closed System
	Centrifugal water pump	:	Open System

Pressure cooker	:	Closed System
Steam boiler	:	Open System

Q. 42. Are the following properties of system intensive or extensive ?

Mass, Density, Weight, Length, Pressure, Temperature, Velocity, Surface area, Potential energy, Strain.

Ans.

Mass	:	Extensive property
Density	:	Extensive property
Weight	:	Extensive property
Length	:	Intensive property
Pressure	:	Intensive property
Temperature	:	Intensive property
Velocity	:	Intensive property
Surface area	:	Extensive property
Potential Energy	:	Extensive property
Strain	:	Intensive property