1.1.1. HEAT

"The energy in transit is termed **heat"**

While Aristotle was of the opinion that fire was one of the four primary elements, Plato thought that the heat was sort of motion of particles; accordingly there are two theories of heat. Any theory should be able to explain the facts given below :

(*i*) Whenever there is an exchange of heat, heat is consumed (heat lost by the hot body is always equal to heat gained by the cold body).

(*ii*) The heat flow takes place from higher to lower temperature.

(*iii*) The substances expand on heating.

(*iv*) In order to change the state of a body from solid to liquid or liquid to gas without rise in temperature, certain amount of heat is required.

(*v*) When a body is heated or cooled its weight does not change.

1.1.3.17. Comparison of work and heat

Similarities :

(*i*) Both are *path functions and inexact differentials.*

(*ii*) Both are boundary phenomenon *i.e.*, both are recognized at the boundaries of the system as they cross them.

(*iii*) Both are associated with a process, not a state. Unlike properties, work or heat has no meaning at a state.

(*iv*) Systems possess energy, but not work or heat.

Dissimilarities :

(*i*) In heat transfer temperature difference is required.

(*ii*) In a stable system there cannot be work transfer, however, there is no restriction for the transfer of heat.

(*iii*) The sole effect external to the system could be reduced to rise of a weight but in the case of a heat transfer other effects are also observed.

1.1.4. DIFFERENCES BETWEEN THERMODYNAMICS AND HEAT TRANSFER

The fundamental differences between thermodynamics and heat transfer are given below :

To understand the difference between thermodynamics and heat transfer, let us consider the cooling of a hot steel bar which is placed in a water bath. *Thermodynamics* may be used to predict the final equilibrium temperature of the steel bar-water combination; however, it will not help us to find out how long it takes to reach this equilibrium condition or what the temperature of the bar will be after a certain length of time before the equilibrium condition is attained. *Heat transfer* on the other hand, may be used to *predict* the *temperatures of both the bar and the water as a function of time.*

Heat transfer theory *combines thermodynamics and rate equations together* (to quantify the rate at which heat transfer occurs in terms of the degree of non-equilibrium).

	Thermodynamics	Heat transfer
1.	It deals with the *equilibrium states* of matter, and precludes the existence of a temperature gradient.	It is inherently a *non-equlibrium process* (since a temperature gradient must exist for exchange of heat to take place).
2.	When a system changes from one equilibrium state to another, thermodynamics helps to determine the quantity of work and heat interactions. It describes how much heat is to be exchanged during a process but does not hint how the same could be achieved.	It helps to *predict the distribution of temperature* and to *determine the rate at which energy is transferred* across a surface of interest due to temperature gradients at the surface, and difference of temperature between different surfaces.

transfer being considered.

1.1.6. MODES OF HEAT TRANSFER

Heat transfer which is defined as the *transmission of energy from one region to another as a result of temperature gradient* takes place by the following three modes :

(*i*) Conduction; (*ii*) Convection; (*iii*) Radiation.

Heat transmission, in majority of real situations, occurs as a result of combinations of these modes of heat transfer. *Example* : The water in a boiler shell receives its heat from the fire-bed by conducted, convected and radiated heat from the fire to the shell, conducted heat through the shell and conducted and convected heat from the inner shell wall, to the water. *Heat always flows in the direction of lower temperature.*

The above three modes are similar in that a temperature differential must exist and the heat exchange is in the direction of decreasing temperature; each method, however, has different controlling laws.

Conduction :

"*Conduction*" is the *transfer of heat from one part of a substance to another part of the same*

substance, or from one substance to another in physical contact with it, without appreciable displacement of molecules forming the substance.

In *solids*, the heat is conducted by the following *two mechanisms* :

(*i*) *By lattice vibration* (the faster moving molecules or atoms in the hottest part of a body transfer heat by impacts some of their energy to adjacent molecules).

(*ii*) *By transport of free electrons* (Free electrons provide an energy flux in the direction of decreasing temperature — For metals, especially good electrical conductors, the electrtonic mechanism is responsible for the major portion of the heat flux except at low temperature).

In case of *gases*, the mechanism of heat conduction is simple. The kinetic energy of a molecule is a function of temperature. These molecules are in a continuous random motion exchanging energy and momentum. When a molecule from the high temperature region collides with a molecule from the low temperature region, it loses energy by collisions.

In liquids, the mechanism of heat is nearer to that of gases. However, the molecules are more closely spaced and intermolecular forces come into play.

Convection :

"Convection" is the transfer of heat within a fluid by mixing of one portion of the fluid with another.

- Convection is possible only in a fluid medium and is *directly linked with the transport of medium itself.*
- Convection constitutes the *macroform* of the heat transfer since macroscopic particles of a fluid moving in space cause the heat exchange.
- The effectiveness of heat transfer by convection depends largely upon the mixing motion of the fluid.

This mode of heat transfer is met with in situations where energy is transferred as heat to a flowing fluid at any surface over which flow occurs. This mode is *basically conduction in a very thin fluid layer at the surface and then mixing caused by the flow*. The heat flow depends on the properties of fluid and is independent of the properties of the material of the surface. However, the shape of the surface will influence the flow and hence the heat transfer.

Free or natural convection. Free or natural convection occurs when the fluid circulates by virtue of the natural differences in densities of hot and cold fluids; the denser portions of the fluid move downward because of the greater force of gravity, as compared with the force on the less dense.

Forced convection. When the work is done to blow or pump the fluid, it is said to be *forced convection*.

Radiation :

"Radiation" is the transfer of heat through space or matter by means other than conduction or convection.

Radiation heat is thought of as *electromagnetic waves or quanta* (as convenient) an emanation of the same nature as light and radio waves. *All bodies radiate heat; so a transfer of heat by radiation occurs because hot body emits more heat than it receives and a cold body receives more heat than it emits*. Radiant *energy* (being electromagnetic radiation) *requires no medium for propagation and will pass through vaccum.*