Heat

Heat is that form of energy which flows from one body to other body due to difference is temperature between the bodies. The amount of heat contained in a body depends upon the mass of the body.

----> If W work is performed and heat produced is H then W/H = J or W= JH where J is a constant called Mechanical Equivalent of Heat. Its value is 4.186 joule/Calorie. It means if 4.186 joule of work is performed, 1 calorie of heat is consumed.
Units of Heat

C.G.S unit : calorie = It is the amount of heat required to raise the temperature of 1 g of pure water through 1°C.

International calorie : It is the amount of heat required to raise the temperature of 1 g of pure water from 14.5°C to 15.5°C.

F.P.S. unit : B.Th.U (British Thermal Unit) = It is the amount of heat required to raise the temp, of 1 pound of pure water through 1°F.

Relations between different units :

1 B.Th.U = 252 calorie

1 calorie = 4.186 joule

1 Therm = 105 B.Th.U.

1 pound calorie = 453.6 calorie.

Temperature : Temperature is that physical cause which decides the direction of flow of heat from one body to other body. Heat energy always flows from body at higher temperature to body at lower temperature.

Measurement of Temperature

Thermometer : The device which measures the temperature of a body is called thermometer.

Scales of temperature measurement

To measure temperature two fixed points are taken on each thermometer. One of the fixed points is the freezing point of water or ice as lower fixed point (LFP).

The other fixed point is the boiling point of water or steam as upper fixed print (UFP).

The temperatures of these fixed points, the no. of fundamental interval between the two fixed points on different temperature scales is shown by the table given below:

Relation between Temperature on different scales

C-0/100 = F-32/180 = R-0/80 = K-273/100 = Ra-492/180

1. Celsius was initially know as centigrade.

2. While expressing temperature on kelvin scale ° (degree) is not used.

3. Freezing point (F.P.) of mercury is -39°C. Hence to measure temperature below this temperature, alcohal thermometer is used. F.P. of alcohal is -115°C.

Range of different thermometers

Mercury Thermometer : from -30°C to 350°C

Constant volume gas thermometer : from -200°C to 500°C (with H_2), below -200°C upto -268°C (with He) above 1000°C upto 1600°C (with N_2 gas and bulb of glazed porcelain)

Platinum resistance thermometer : from - 200°C to 1200°C

Thermocouple thermometer : from - 200°C to 1600°C

Total Radiation Pyrometer

When a body is at high temperature, it glows brightly and the radiation emitted by the body is directly proportional to the fourth power of absolute temperature of the body. Radiation pyrometer measures the temperature of a body by measuring the radiation emitted by the body.

This thermometer is not put in contact with the body. But it can not measure temperature below 800°C because at low temperature emission of radiation is very small and can not be detected.
Specific Heat Capacity : Specific heat capacity of a material is the amount of

heat required to raise the temperature of unit mass of substance through 1°. Its SI unit is Joule / kilogram kelvin (J/kg.k)

----> One calorie of heat is required to raise the temperature of 1 gram of water through 1°C. Hence specific heat capacity of water is 1 cal / gram °C.

1 calorie/gram °C = 4200 Joule/kg kelvin.

Thermal Expansion

When a body is heated its length, surface area and volume increase. The increase in length, area and volume with the increase in temperature are measured in terms of coefficient of linear expansion or linear expansivity (a), coefficient of superficial expansion or superficial expansivity (p) and coefficient of cubical expansion or cubical expansivity (?).
Relation between a, ß and ?.
a : ß : ? = 1 : 2 : 3 or, ß = 2 a and ? = 3 a

Anomalous expansion of water : Almost every liquid expands with the increase in temperature. But when temperature of water is increased from 0°C to 4°C, its volume decreases. If the temperature is increased above 4°C, its volume starts increasing. Clearly, density of water is maximum at 4°C.

Transmission of Head : The transfer of heat from one place to other place is called transmission of heat. There are three modes of heat transfer—(i) conduction, (ii) convection and (iii) radiation.

Conduction : In this process, heat is transferred from one place to other place by the successive vibrations of the particles of the medium without bodily movement of the particles of the medium. In solids, heat transfer takes place by conduction.

Convection : In this process, heat is transferred by the actual movement of particles of the movement from one place to other place. Due to movement of particles, a current of particles set up which is called convection current.

In liquids and gases, heat transfer takes place by convection.

----> Earth's atmosphere is heated by convection.

Radiation : In this method transfer of heat takes place with the speed of light without affecting the intervening medium.

Newton's law of cooling : The rate of loss of heat by a body is directly proportional to the difference in temperature between the body and the surrounding.

Kirchhoff's law : According to Kirchhoff's law, the ratio of emissive power to absorptive power is same for all surfaces at the same temperature and is equal to emissive power of black body at that temperature. Kirchhoff's law signifies that good absorbers are good emitter.
If a shining metal ball with some black spot on its surface is heated to a high temperature and seen in dark, the shining ball becomes dull but the black spots shines brilliantly, because black spot absorbs radiation during heating and emit in dark.

Stefan's law : The radiant energy emitted by a black body per unit area per unit time (i.e. emissive power) is directly proportional to the fourth power of its absolute temperature.

i.e. E ? T4 or, E = sT4

where a is a constant called Stefan's constant.

Latent heat or heat of transformation
The amount of heat required to change the state of unit mass of substance at constant temperature is called latent heat.
If Q heat is required to change the state of a substance of mass m at constant temperature and L is the latent heat, then Q = mL.
S.I. unit of latent heat is Joule/kilogram.

Any material has two types of latent heat.

(i) Latent heat of fusion : It is the amount of heat energy required to convert unit mass a substance from solid state to liquid state at its melting point. It is also the amount of heat released by unit mass of liquid when changed into solid at its freezing point.

(ii) Latent heat of vapourisation : It is the amount of heat required to change unit mass of a substance from liquid state to vapour state at its boiling point. It is also the amount of heat released when unit mass of a vapour is changed into liquid.

Sublimation : Sublimation is the process of conversion of a solid directly into vapour.

----> Sublimation takes place when boiling point is less than melting point.

----> Sublimation is shown by camphor or ice in vacuum.

Hoar Frost : Hoar frost is just the reverse process of sublimation i.e. it is the process of direct conversion of vapour into solid.

----> Steam produces more severe burn than water at same temperature because internal energy of steam is more than that of water at same temperature.
Relative Humidity : Relative humidity is defined as the ratio of amount of water vapour present in a given volume of atmosphere to the amount of water vapour required to saturate the same volume at same temperature.
The ratio is multiplied by 100 to express the relative humidity in percentage.

----> Relative humidity is measured by Hygrometer.

----> Relative humidity increases with the increase of temperature.

Air conditioning : For healthy and favourable atmosphere of human being, the conditions are as follows

(i) Temperature : from 23°C to 25°C.

(ii) Relative humidity : from 60% to 65%.

(iii) Speed of air : from 0.75 meter/minute to 2.5 meter/minute

Thermodynamics

First law of thermodynamics : Heat energy given to a system is used in the following two ways :

(i) In increasing the temperature and hence internal energy of the system.

(ii) In doing work by the system.

If ?Q = heat energy given to the system
?U = Increase in the internal energy of the system.
?W = work done by the system

Then, ?Q = ?U + ?W is the mathematical statement of first law of thermodynamics.

----> First law of thermodynamics is equivalent to principle of conservation of energy.

Isothermal Process : If the changes are taking place in a system in such a way that temperature of the system remains constant throughout the change, then the process is said to be an isothermal.

Adiabatic Process : If the changes are taking place in a system in such a way that there is no exchange of heat energy between the system and the surrounding, then the process is said to be an adiabatic process.

----> If carbon dioxide is suddenly expanded, it is changed into dry ice. This is an example of adiabatic process.

Second Law of Thermodynamics : The first law of thermodynamics guarantees that in a thermodynamic process, energy will be conserved. But this law does not tell whether a given process in which energy is conserved will take place or not. The second law of thermodynamics gives the answer.
Through this law can be stated in many forms, the following two forms are worth mentioning :

Kelvin's statement : Whole of the heat can never be converted into work.

Clausius statement : Heat by itself can not flow from a colder body to a hotter body.
Heat Engine : Heat energy is a device, which converts heat energy into mechanical work continuously through a cyclic process. Every heat engine basically consists **of the three parts :** (i) source (a hot body) (ii) sink (a cold body) and (iii) a working substance.

Heat engine may be devided into two types :

(i) Internal Combustion Engine : In this engine, heat is produced in the engine itself. Example : Otto engine or petrol engine (efficiency = 52%), Diesel engine (efficiency = 64%)

(ii)External Cumbustion Engine : In this engine heat is produced outside the engine. Steam engine is an example of external cumbustion engine. (efficiency - 20%).

Refrigerator or Heat Pump : A refrigerator is an apparatus which transfers heat energy from cold to a hot body at the expanse of energy supplied by an external agent. The working substance here is called refrigerant. In actual refrigerator, vapours of freon (CC12F2) acts as refrigerant.