Heat

Heat

- Heat is the form of energy which produces the sensation of warmth. Its SI unit is joule and other unit calorie (1 cal = 4.2 Joule) .
- The transfer of heat is always from hotter to colder body.

Temperature

- Temperature is measure of hotness or coldness of a body.
- The heat flows from one body to another due to the difference in their body temperature.

Scale of Temperature

- To measure the temperature of a body following temperature scales are used.

— **Celsius scale** of temperature freezing point is 0°C Boiling point of water is 100°C

— **Fahrenheit scale** of temperature ice point or freezing of water = 32° F

Boiling point of water = 212° F

— **Kelvin or absolute scale** of temperature ice point of water = 273° K

Boiling point of water = 373° K

— **Reaumur scale** of temperature ice point of water is 0° R,

Boiling point of water = 80°R

— **Rankine scale** of temperature ice point /freezing point of water

= 491.67°R Boiling point of water

= 671.641° R

Relation between Different Scales of Temperature

Different scales of temperature are related as follows:

K =273+ °C

- At temperature – 40°C = – 40°F, Clesius scale is equal to Fahrenheit
- The temperature at which the three phases of water remains at equilibrium is called triple point of water (273.16 K)

Thermometers

- The instruments used to measure temperature of a body is called thermometer.

Thermometers are of following three types

1. **Clinical thermometer** It is used to measure human body temperatures and ranges from 96° F to 110°F or 35°C to 43°C.
2. **Electronic thermometer** Basic components of an electronic thermometer are thermistors or thermoresistors. Range of electronic thermometer is – 40° to 450°F.
3. **Other thermometers** These include constant volume gas thermometer, platinum resistance thermometer etc.

- Clinical thermometer measures temperature in degree fahrenheit (°F).
- In thermometer, mercury is commonly used through a wide range from –30°C to 300°C.
- Thermometer was developed by **Galileo** who found that the gases expand on heating.

Thermal Expansion

- The expansion of a body caused by heat is known as thermal expansion.

Thermal Expansion of Solids

Thermal expansion of solids is of three types

1. Expansion in length on heating, is called **linear expansion**. The increase in length of a rod of unit length of a substance due to increase in its

temperature by 1°C is called the **coefficient of linear expansion** of the substance of that rod. It is represented by α.

— Its unit is $°C^{-1}$.

2. Expansion in area on heating, is called **superficial expansion**. Coefficient of superficial expansion is given as

— Its unit is $°C^{-1}$.

3. Expansion in volume on heating, is called **volume expansion** or **cubical expansion**.

Coefficient of volume or cubical expansion is given as

— Its unit is $°C^{-1}$

Relation between Coefficients of Expansions

- Coefficients of thermal expansions are related as

$\beta = 2\alpha$ and $\gamma = 3\alpha$

and $\alpha : \beta : \gamma = 1 : 2 : 3$

- In laying a railway line, a small gap is left in between two iron rails otherwise railway line will become curved on heating in summer.
- Telephone wires are not tighten on poles because in winter, wires get contract and can break.

Thermal Expansion of Liquids

- In liquids, only expansion in volume takes place on heating.

Expansion of liquid is of two types:

- When expansion of the container, containing liquid, on heating, is not taken into account, then observed expansion is called **apparent expansion** of liquids.
- When expansion of the container, containing liquid, on heating, is also taken into account, then observed expansion is called **real expansion** of liquids.

where, and , are coefficients of real and apparent expansion of liquids and = coefficient of cubical expansion of the container.

Anomalous Expansion of Water

When temperature of water is increased from 0°C, then its volume decreases up to 4°C, becomes minimum at 4° C and then increases. This behavior of water expansion around 4°C is called, anomalous expansion of water.

Thermal Expansion of Gases

There are two types of coefficient of expansion in gases

— At constant pressure, the change in volume per unit volume per degree celsius, is called **volume coefficient** ().

— At constant volume, the change in pressure per unit, pressure per degree celsius, is called **pressure coefficient** ().

Calorimetry

- Amount of heat required to raise the temperature of 1 g of water by 1°C is called 1 calorie.
- Calorimetry states that heat lost by hotter body equals the heat gained by colder body.

Specific Heat

- The amount of heat required to raise the temperature of unit mass (m) of a substance through 1°C, is called its specific heat (s).
- It is denoted by s and its unit is 'cal/g°C or Joule/g°/C.
- The specific heat of water is 4200 J/kg^{1}/°C or 1000 cal/ g^{1}/° C^{-}, which is high compared with most other substances. Therefore, water is used as coolant in radiator in vehicle and hot water is used for the fermentation.
- Heat energy given or taken to change the temperature of a body is given by

$Q = ms\Delta\theta$

where, m = mass of the body

and $\Delta\theta$ = change in temperature.

- The amount of heat required to raise the temperature of 1 mole of a gas by 1°C is called molar specific heat.

Latent Heat

- The heat energy absorbed or released at constant temperature per unit mass for change of state, is called **latent heat**.
- It is denoted by L and its SI unit is cal/g or kcal/kg.
- Heat energy absorbed or released during change of state is given by

$Q = mL$

where, m = mass of the substance.

- Latent heat of fusion of ice is 80 cal/g.
- Latent heat of vaporisation of steam is 536 cal/g.

Thermodynamics

- The branch of physics which deals with the study of relation of heat energy with different types of energy is called thermodynamics.

Zeroth Law

- Zeroth law of thermodynamics tells about thermal equilibrium.

First Law

- As per first law about energy, heat given to a substance is equal to sum of change in internal energy and work done.

Second Law

- In second law work can be converted into heat and vice-versa but conversion is not possible with 100% efficience.
- It is impossible for a machine operating in a cyclic process to convert heat completely into work, it is **kelvin's statement**.
- Heat by itself can not transfer from a colder to a hotter body. It is **clausius statement**. Refrigerator is based on this statement.
- **Heat engine** is a device which converts heat into mechanical work. Internal combustion and external combustion heat engine are two types of heat engine.

- Car engine uses coolant added with water to reduce harmful effects like corrosion, rusting etc. Such as ethylene glycol, polossium dichromate etc,
- **Carnot's theorem** tells about maximum efficiency of heat engine. It refers to carnot cycle.
- **Entropy** measures the molecular disorder of a system and is a thermodynamic function depending only on the temperature of the system.
- **Evaporation** is a process in which molecules escape slowly from the surface of a liquid.
- For a given liquid the rate of evaporation demands on the temperature and area of evaporating surface.
- **Refrigerator** is a device used for cooling things by the evaporation and compression of a volatile liquid inside a copper coil.

Humidity

- The presence of moisture in the atmosphere, is called humidity.
- The amount of water vapour present in the unit volume of atmosphere, is called **absolute humidity**.
- The **relative humidity** of air at a given temperature is the ratio of mass of water vapour present in a certain volume of air to the mass of water vapour required to saturate the same volume of air at the same temperature, multiplied by 100.
- Relative humidity is measured by **hygrometer**.
- Relative humidity of about 50% is considered comfortable at temperature 22° – 25° C.
- If the relative humidity is very low in air, then lips become dry and cracks appear in them.
- If relative humidity is very high in air then the sweat from our body does not evaporate readily and therefore we feel uncomfortable.
- **Air conditioning** provides comfortable conditions by regulating temperature and humidity.

Transmission of Heat

- Heat can be transferred from one place to another by process of transmission.
- There are three methods of transmission of heat.

Conduction

- The mode of transmission of heat in solids from higher temperature part to lower temperature part without actual movement of the particles, is called conduction.
- Transmission of heat in solids takes place mainly through conduction.
- Metals are good conductors of heat.
- Wood, cotton, wool, glass are bad conductors of heat, dry air is also a bad conductor of heat.
- Woollen clothes do not allow the heat of our body to escape and therefore we feel warm.
- On a cold night two thin blankets give more warmth than a single thick blanket because the layer of air between the two blankets works as a better insulator.
- Refrigerators and ice-boxes have double walls having thermocol between them which minimise heat gain by conduction.

Convection

- The mode of transmission of heat in fluids (liquids and gases) due to actual movement of the particles, is called convection.
- In liquids and gases, heat is transmitted by convection.
- When a liquid in a vessel is heated at the bottom, the liquid at bottom gets heated and expands.
- Due to its lower density, hot liquid rises and its place is taken by cold liquid from above. Convection currents are set up in the liquid until the temperature of the whole liquid becomes same.
- The cooling unit in a refrigerator is fitted near the top as cold air move downward and keeps cool the whole interior.
- Radiator in a motor car works on the principle of convection.

Newton's Law of Cooling

The rate of loss of heat from a body is directly proportional to the difference in temperatures of the body and its surroundings.

If we take hot water and fresh water and put it in a refrigerator, then rate of cooling of hot water will be faster than the fresh tap-water.

- **Sea Breeze** During day time, the seashore warms up much faster than sea water. Hot air over the seashore rises and cooler air from sea water moves towards seashore to take its place resulting in a sea breeze.
- **Land Breeze** At night, land cools faster than sea water. Now hot air over sea water rises and cooler air from land moves towards sea to take its place and resulting in a land breeze.
- Cloudy night are warmer than clear night because clouds reflect the radiations emitted by the earth at night and keep it warm.

Radiation

- The process of heat transmission in the form of electromagnetic waves, is called radiation.
- Radiation does not require any medium for propagation and it propagates without heating the intervening medium.

Black Body

- A body that absorbs all the radiation incident on it is called perfectly black body.
- Ratio of heat absorbed (radiation) to total incident radiation for a body is called absorptive power (a) of body. It has no unit.
- Amount of heat radiation per unit area of the surface at a given temperature is called emissive power of the surface.
- Its unit is $J/m^2 - s$.
    - The ratio of emissive power and absorptive power of a body is always same. It is equal to emissive power of a black body. This is known as **Kirchhoff's law**.
    - White colour is a bad absorbers and good reflectors of heat radiations while black colour is good absorbers and bad reflectors of heat. Therefore, clothes of light colours give better feeling in summer and clothes of dark colours give better feeling in winter.

Stefan's Law

- It states that "The amount of heat energy (E) radiated per second by unit area of perfectly black body is directly proportional to the fourth power of absolute temperature (T) of the body."

$E \propto T^4$

- Good absorbers are good emitters and poor absorbers are poor emitters.