UNIT – 3 (THERMAL PHYSICS)

Introduction

Thermodynamic is the branch of science concerned with heat and temperature and their relation to energy and work. It states that the behavior of these quantities is governed by the four lawsof thermodynamics, .

3.1. Fundamental definition

3.1.1. Heat

Heat is a measurement of energy. The total energy of all the molecular motion inside theobject is known as heat. It is measured as calorie and Joule.

3.1.2. Temperature

Temperature is a measure of average heat or thermal energy of the molecule in a substance. Itis measured as Kelvin, Celsius and Fahrenheit.

3.1.3. Temperature gradient

The rate of fall of temperature with respect to the distance or thickness of the material iscalled temperature gradient.

3.1.4. Specific heat capacity

Specific heat capacity is defined as the amount of heat is required to raise the temperature ofunit mass of substance through one Kelvin.

3.1.5. Thermal diffusivity

The ratio of thermal conductivity to the thermal capacity per unit volume is known as thermaldiffusivity.

3.1.6. Thermal Conductivity

The quantity of heat conducted per second through unit area of the material when unittemperature gradient is maintained. Its unit is $Wm^{-1}K^{-1}$.

$$K = \frac{Qx}{(\theta_1 - \theta_2)t}$$

3.1.7. Laws of thermodynamics

- **Zeroth law of thermodynamics** – If two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other.
- **First law of thermodynamics** – Energy can neither be created nor destroyed. It can onlychange from one form to another form.
- **Second law of thermodynamics** – The entropy of an isolated system is always increasing.
- **Third law of thermodynamics** – As temperature approaches absolute zero, the entropy of asystem approaches a constant minimum.

Transfer of heat energy

Heat can be transferred from one place to the other place by three different ways. They are,

1. Conduction
2. Convection
3. Radiation

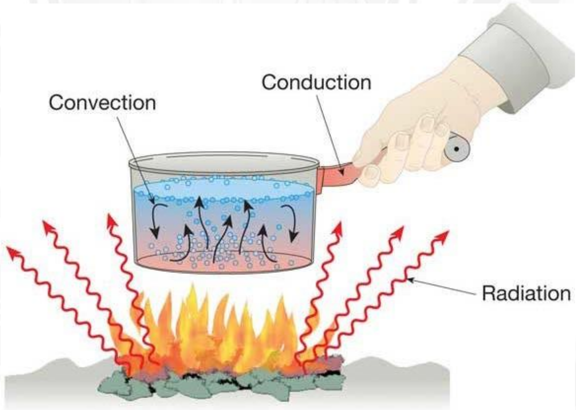

Figure 3.1.1 Transwer of heat energy

3.1.8. Conduction

Conduction is the process in which heat is transmitted from the hot end to the cold end of a body without the motion of the particles of the body.

If a metallic rod is heated form one end, we can see that the temperature of the other end also rises, which indicates that the heat is travelled from one end to the other end of the rod.

Due to the gain of heat energy, the amplitude of vibrating particles at the hot end increases. During this vibration, the vibrating particles collide with the adjacent particles and share their energy with them. This vibrational energy is passed from layer to layer towards the cold end. At the same time, each individual particle remains at its equilibrium position. This process of conduction is prominent in the case of solids.

3.1.9. Convection

Convection is the process in which heat is transmitted from one place to the other place by theactual movement of the heated particles.

In this mode of transmission, the particles themselves propagate the heat. Conduction is the normal mode of propagation of heat in liquids and gases. The regions of fluids, which are heated, expand and become less dense thereby carrying heat to the other regions.

3.1.10. Radiation

Radiation is the process in which heat is transmitted from one place to the other directly without the necessity of the intervening medium.

In this mode of propagation of heat, no material medium is required for the transmission of heat. If we are near to an open fire or we hold a hand near to a hot bath, we feel some hotness. In addition, the heat from the sun reaches us by this process.

Heat radiation can pass through vacuum and gas. Their properties are similar to lightradiations. Heat radiations are also from a part of the electromagnetic spectrum.

Thermal expansion

The property involves the increase in the length or area or volume of a matter as the temperature increases. The temperature of a body causes expansion or contraction of that body. All three states of matter (solid, liquid and gas) expand on heating and contract on cooling. This is called thermal expansion. Thermal expansion is the basic principle that a thermometer works on.

3.1.11. Thermal expansion of solids

When a solid is heated, its atoms vibrate faster about their fixed points. The relative increase in the size of solids when heated is therefore small. Metal railway tracks have small gaps so that when the sun heats them, the tracks expand into these gaps and do not buckle. The stress developed inside the metal to regain its original position is called thermal stress.

Explanation

Let us consider a metal rod of length 'l' at a temperature T. When the rod is heated to the temperature from T to T + θ, then the length of the rod increases, linearly from l to $l + dl$ as shown in figure.

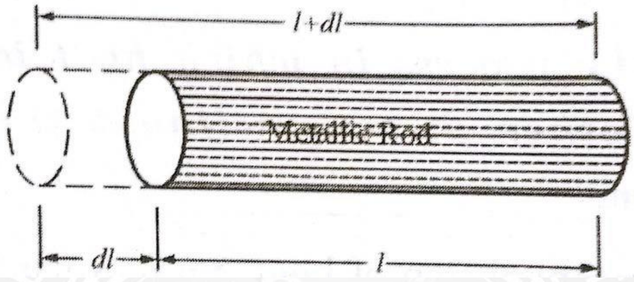

Fig 2.1.2 Expansion of solid

The co-efficient of the thermal expansion

$$\alpha = \frac{dl}{l\theta} \ldots\ldots\ldots\ldots(1)$$

If $\theta = 1$, then

$$\alpha = \frac{dl}{l}$$

Thus, the co-efficient of thermal expansion can be defined as the ratio between the changes inlength to the original length per unit rise of temperature.

The coefficient of thermal expansion describes how the size of an object changes with change in temperature. Specifically, it measures the fractional change in size per degree change in temperature at a constant pressure.

3.1.12. Thermal Expansion of Liquids

Liquids do not have a definite shape. They take the shape of the container. Thus, we can specify a liquid by it is volume. Hence, we can speak of volume expansion only for liquids. Expansion of liquids is much greater than that of solids.

Explanation

A liquid is heated in a container. Heat flows through the container to the liquid.

This means that the container expands first, due to which the level of the liquid falls. When the liquid gets heated, it expands more and beyond its original level. We cannot observe the intermediate state. We can only observe the initial and the final levels. This observed expansion of the liquid is known as the apparent expansion of the liquid.

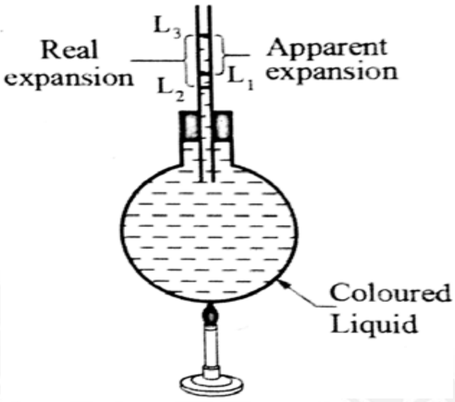

Fig 2.1.3 Expansion of liquid

If we consider the expansion of the container also and measure the total expansion in volume of the liquid, then the expansion is termed as the absolute expansion of the liquid.

When the liquid gets heated, it expands much more than the container and its level rises to L_3. We can only observe the increase in level from L_1 to L_3. Intermediate level L_2 goes unnoticed.

The expansion we measure is the apparent expansion of the liquid. The corresponding coefficient is coefficient of apparent expansion.

The coefficient of apparent expansion is defined as the ratio of apparent increase in volume of the liquid to its original volume for every degree rise in temperature.

$$coefficient\ of\ apparent\ expansion = \frac{increase\ in\ Volume}{(Original\ volume)(increase\ in\ temperature)}$$

$$= \frac{\Delta v}{(t_2 - t_1)}$$