Chapter 11

Thermal Properties of Matter

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11.1 Introduction

When two bodies at different temperatures are placed in contact, the temperature of the hot body decreases and that of cold body increases. If these two bodies are left as such for sometime, they reach an equilibrium temperature. In such processes we say that heat is transferred from a body at higher temperature to a body at lower temperature.

Early investigators believed that heat was an invisible material substance called "***Caloric (fluid)*** which flows from one body to another. Thus the calorie theory was developed. According to calorie theory, calorie can neither be created nor be destroyed. Heat flows until the calorie levels of the two bodies become equal. This theory was successful in explaining heat transfer, but failed in explaining various other facts.

This picture of heat was discarded through experimental observation made at the end of the 18th century by **Benjamin Thompson**. According to him, heat is not a substance but it is a form of energy, which can be transferred from one body to another as a result of difference in temperature of the two bodies. Later when the concept of mechanical energy was introduced, one found that some mechanical energy

Curriculum Objectives

- To develop clear idea about temperature, heat and laws of thermodynamics through discussions, examples and simple experiments.
- To develop the idea thermodynamic variables, phase diagram and different thermodynamic processes through discussions and experiments.
- To develop curiosity in seeking heat expended processes in daily life and in nature through discussions and experiments.
- To develop a clear idea of heat capacity and specific heat capacity through discussions and problem solving.
- To understand various types of heat engines and their efficiency through discussions, derivations and projects.

gets lost whenever there is friction in mechanical system. This loss in mechanical energy appears as thermal energy. Heat is nothing but the thermal energy.

The connection between the mechanical and thermal energy was first suggested by Thompson, but the equivalence of these two forms of energy was first established by James Prescott Joule in 1840.

11.2 Temperature and Heat

Thermal properties of matter fundamentally depend on the quantities temperature and heat.

Temperature *of a body is the degree of hotness or coldness of the body.* In the case of a hot body, we say its temperature is high and for a cold body we say that its temperature is low. Hot and cold are relative ideas.

On a hot day, if you take a cup of hot tea and an ice cube, then tea cools down and ice cube gets warmed. Here, tea liberates heat and ice cube absorbs it from surroundings, because there is a tempearature difference between the body and its surroundings. Generally the heat energy is the energy transferred between two bodies (or to surroundings) due to the temperature difference. It is clear from the above example, that heat flows from a region of high temperature to a region of low temperature.

S.I unit of temperature - K (kelvin) and of heat is J (joule)

Difference between heat and temperature

Heat: Heat is an extensive property (depends on amount of substance).

Temperature: Temperature is related to average amount of kinetic energy in a substance. Temperature is an intensive property (doesn't depend on the amount of substance).

11.3 Measurement of Temperature

The direction of flow of heat is determined by the factor temperature. Measurement of temperature is a must and the branch of physics which deals this aspect is known as ***thermometry.***

The history of thermometry starts around 1600 AD in Italy with the invention of Air - Thermoscope. It is used to measure the changes in temperature and pressure. The first liquid thermometers were invented around 1650. Thermometers are used to measure the temperature of a body. In 1714, mercury thermometer came into existence. The thermometric property of mercury is used to define three temperature scales, Fahrenheit , Celsius and Reaumer. In these scales, the melting point of ice and boiling point of water at one atmospheric pressure are used as standard references. There was vast development in thermometry in the 19th century. Electrically based temperature sensors such as thermocouples and resistance thermometers are the major developments in this field. The theoretical developments of thermodynamic, by Carnot and Kelvin, forced to introduce a new scale of temperature which is used now a days in scientific work. This scale of temperature is called absolute scale or Kelvin scale or Ideal gas scale of temperature. Out of all these different scales of temperatures, Fahrenheit, Celsius and Kelvin scales are in common use.

A comparative study of these scales and their conversions are given below.

11.3.1 Temperature Scales

TABLE 1

°C: degree Celsius (centigrade), °F: degree Fahrenheit, K: Kelvin

	°C	°Reaumur	°F	K
Boiling point of water (at 1 atm = 101325 Pa)	100	80	212	373.15
Freezing point of water (at 1 atm = 101325 Pa)	0	0	32	273.15
Interval freezing point-boiling point of water (at 1 atm = 101325 Pa)	100	80	180	100
Triple point of water (solid-liquid-gas equilibrium)	0.01	0.008	32.02	273.16

Conversion Formulae

$$\frac{t_F - 32}{180} = \frac{t_C}{100} = \frac{t_R}{80};$$

a °C = (4/5)a °Reaumur = [32+(9/5)a] °F

b °Reaumur = (5/4)b °C = [32 + (9/4)b] °F

c °F = (5/9)(c – 32) °C = (4/9)(c – 32) °Reaumur

t°C = (t + 273.16)K, Approximately, t°C = (273 + t)K

eg: 62° F

t_F = 62° F

$$\therefore \frac{t_C}{100} = \frac{62-32}{180} = \frac{30}{180} = \frac{1}{6}$$

$$t_C = \frac{100}{6}\ °C = 16.67°C$$

$$\frac{t_R}{80} = \frac{62-32}{180} = \frac{1}{6}$$

$$t_R = \frac{80}{6}°R = 13.33°\ R$$

In kelvin scale; K = 273 + 16.67 = 289.6 K

You must know

WHY KELVIN SCALE

Earlier gas thermometers made use of the melting point of ice and boiling point of water as standard temperatures. But these points are sensitive to the dissolved impurities in water and hence temperature measurements may not be accurate. Hence a new procedure based on a single fixed point was adopted in 1954. Triple point of water is taken as the reference point. Triple point of water is that temperature and pressure at which water co-exists in all its three forms (ice, water and steam). The triple point of water occurs at a temperature of 0.01° C and a pressure of 4.58 mm of mercury. In Kelvin scale the temperature was arbitrarily set at 273.16 kelvin (273.16 K) and one Kelvin is defined as $\frac{1}{273.16}$ of the temperature of the triple point of water. The measurement of temperature on Kelvin scale is independent of the nature of the thermometric substance used.