Sharjah Indian School- Boys Wing

Notes on: **Thermal Properties of Matter'**

HEAT AND TEMPERATURE

Heat is a form of energy. It is the measure of the total internal energy possessed by the molecules of a substance in a given state.

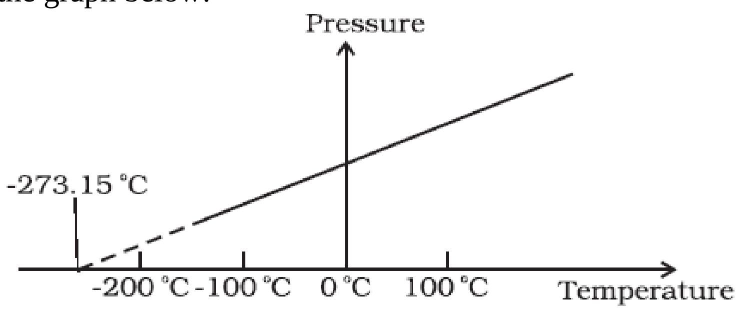
Its S.I unit is Joule (J). c.g.s unit:- Calorie 1 cal = 4.2 J.

Temperature is the degree of hotness or coldness of a body. It is the measure of the average internal energy possessed by the molecules of a substance.

Unit:- Kelvin (K), Celsius (^oC) or Fahrenheit (^oF).

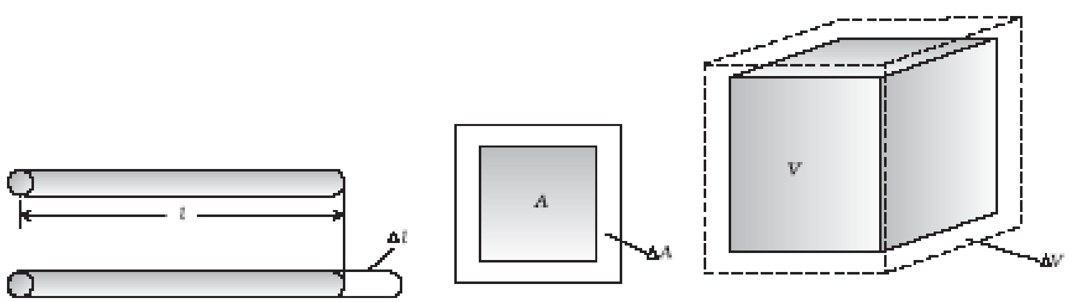
These units are related as: T = t + 273 and $\frac{C}{100} = \frac{F-32}{180}$

The lowest possible (theoretically) temperature is called absolute zero (-273.15^{o}C), as indicated in the graph below:



THERMAL EXPANSION

When a substance is heated, the molecules gain kinetic energy so that they move more vigorously. Hence they require more space to occupy and this leads to thermal expansion.
The different ways to express thermal expansion are: Linear expansion, Area expansion (Superficial expansion) and Volume expansion. They are illustrated in the figure given below:



Coefficient of linear expansion (linear expansivity) is defined as the fractional change in length per unit rise in temperature.

i.e. $\alpha = \frac{\Delta L}{L(T_2 - T_1\}}$ Its unit: K^{-1}

Coefficient of area expansion (areal expansivity) is defined as the fractional change in area per unit rise in temperature.

i.e. $\beta = \dfrac{\Delta A}{A(T_2 - T_1\}}$ Its unit: K^{-1}

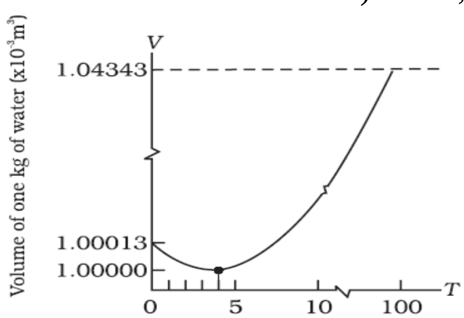
Coefficient of volume expansion (cubical expansivity) is defined as the fractional change in volume per unit rise in temperature.

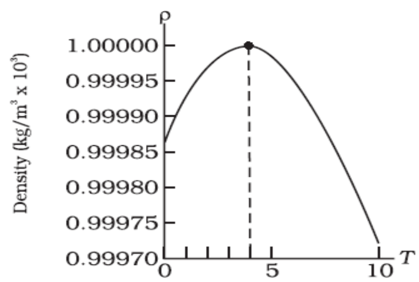
i.e. $\gamma = \dfrac{\Delta V}{V(T_2 - T_1\}}$ Its unit: K^{-1}

Relation between α, β and γ [Refer Note Book]

Different substances possess different expansivities. This fact is made use of in bi-metallic strips used in thermostats.

Water has a peculiar property of expansion. It contracts on heating upto 4^oC and further it expands on heating. This phenomenon is called anomalous expansion. This property is most helpful in preserving aquatic life in ponds etc. in cold countries. Thus water has maximum density (and hence minimum volume) at 4^oC, as illustrated below:





Applications of thermal expansion:- (i) Gaps are left in the rails of the railway track, to provide space for the expansion during summer. (ii) Telephone cables are given ‘sag’ when they are laid between poles.

<u>SPECIFIC HEAT CAPACITY</u>

Specific heat capacity (c) of a substance is the amount of heat required to raise the temperature of unit mass of a substance through unit rise in temperature.

Its unit:- $JKg^{-1}\ K^{-1}$

Hence the amount of heat needed to raise the temperature of ‘m’ mass of a substance through ΔT temperature is given by **Q = mcΔT**

Molar specific heat capacity (C) of a substance is the amount of heat required to raise the temperature of one mole of a substance through unit rise in temperature.

Its unit:- $Jmol^{-1}\ K^{-1}$

Hence the amount of heat needed to raise the temperature of ‘n’ moles of a substance through ΔT temperature is given by **Q = nCΔT**

However, a gas has two values of specific heat capacity. A gas can be heated by keeping either pressure or volume constant.

At constant volume, the heat supplied is used only to raise the internal energy, thereby, rising temperature. But when heated at constant pressure, the heat is used not only to raise the internal energy, but to do work for the expansion of the gas also. Thus greater amount of heat is needed to increase the temperature of a gas at constant pressure. So, a gas has two specific heats – Sp. Heat at constant volume **(Cv)** and that at constant pressure **(Cp).** It also shows that **Cp > Cv.**

Further, water has the highest specific heat capacity compared to other substances. For this reason water is used as a coolant in automobile radiators as well as a heater in hot water bags. Due to the high specific heat capacity, the water warms up slower than the land during summer and consequently wind from the sea has a cooling effect. Sea breeze and land breeze also are the consequences of this property of water.

CALORIMETRY

Calorimetry means measurement of heat. When a hot body is brought in contact with a cold body, the heat lost by the hot body is equal to the heat gained by the colder body, provided no heat is allowed to escape to the surroundings. This principle is termed as 'the principle of mixtures.' A device in which heat measurement can be made is called a calorimeter. It consists a metallic vessel and stirrer of the same material like copper. The vessel is kept inside a wooden jacket which contains heat insulating materials. There is an opening in the outer jacket through which a thermometer can be inserted into it.

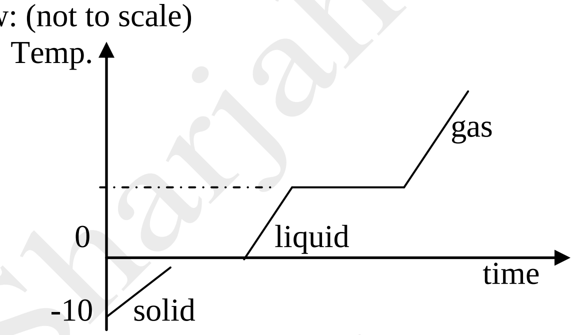
[**Refer example 11.3 of the text book**, to learn how to determine the specific heat capacity of a substance by the method of calorimetry.]

LATENT HEAT (L)

It is the heat required to convert unit mass of a substance completely from one state to another, without any change in the temperature. Unit: J/kg

Hence the heat needed to change the state of 'm' mass of a substance completely at constant temperature is given by, **Q = mL**

The time-temperature graph of ice from -10^{o}C, under constant supply of heat can be shown as below: (not to scale)



[**Refer example 11.4 and 11.5 of the text book]**

<u>*TRANSFER OF HEAT*</u>

Conduction is the process of transfer of heat from one point to another without the actual movement of molecules. Hence it takes place in solids.
At steady state of flow, the heat conducted per second is a constant throughout.
According to Newton,
The heat conducted per second through a conductor is directly proportional to the area of cross-section and the temperature gradient between two layers of the conductor.

i.e. $\frac{Q}{t} \alpha A \frac{T_1 - T_2}{x}$

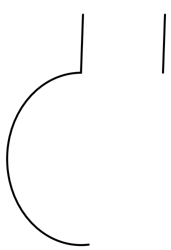
or, $\boxed{\frac{Q}{t} = kA\frac{T_1 - T_2}{x}}$, where k is a constant called thermal conductivity of a substance.

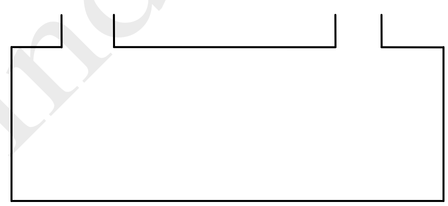
It is defined as the rate of conduction of heat through a conductor of unit area of cross-section, when there is unit temperature gradient between two layers.

S.I unit: $Wm^{-1}K^{-1}$

Different substances have different thermal conductivities. Air and water are poor conductors of heat.

Convection is a mode of heat transfer by actual motion of matter. It is possible only in fluids.
Convection in water and that in air are illustrated in the diagrams given below:





Natural convection is responsible for the winds on the surface of the earth, convection currents in oceans etc. Hot water systems make use of the phenomenon of convection in water.

Radiation:- The mechanism of heat transfer without the help of an intervening medium is called radiation. Heat radiations from the Sun reach the earth by this process. The radiant energy is given out from hot objects in the form of Infrared radiations named 'thermal radiations'. These radiations, when fall on objects, they get heated.

Properties of thermal radiations

1. Can travel in vacuum with the same speed as that of light. i.e. 3×10^8 m s^{-1} .
2. They can be reflected and refracted.
3. They are electromagnetic waves in nature.
4. The amount of heat that a body can absorb by radiation depends on the colour of the body.

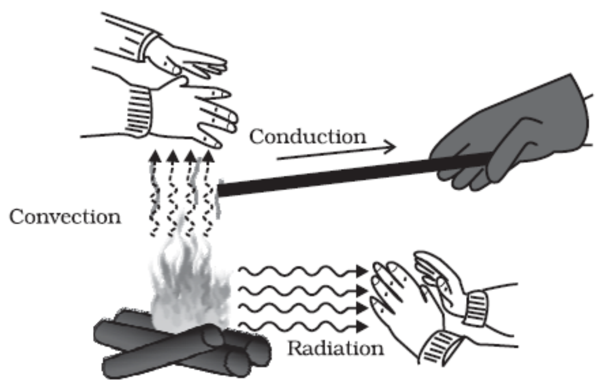
[For more applications of this fact, read the text book page:290]

Qns. 1. Why do we wear white or light coloured clothes in summer, whereas dark coloured clothes in winter?

2. The bottoms of the utensils for cooking food are blackened. What merit does it serve?

3. What mechanism is made use of in Vacuum Flask?

The three modes of transfer of heat are indicated in the figure given below:



NEWTON'S LAW OF COOLING

It states that the rate of loss of heat from a body is directly proportional to the mean difference in temperature of the body and the surroundings, if the difference in temperature is small.

i.e. $\boxed{Q \,\alpha\, (T - T_0)}$

where T is the temperature of the body and T_0, the temperature of the surroundings.

The variation of temperature with time of a hot liquid is given beside. It shows that, the higher the temperature of the body, the greater is the rate of loss of heat. This curve is called a 'cooling curve'.