UNIT 4 HEAT MEASUREMENT part1

4.0 MAIN CONTENT

4.1 Concept of Heat

Prescot Joule first showed that heat is a form of energy in an experiment in which mechanical work (energy) was transformed into heat. Other scientists also showed that heat from fuel, such as gasoline in an engine, may be transformed to mechanical energy when the engine is used to drive carts, trains and aeroplanes. In an electric power station, heat from fuel is changed to electrical energy. The unit of energy is Joule (J) which is also the unit of measuring mechanical energy and electrical energy. We also have larger units such as kilojoule (KJ) and megajoule (MJ). Power, is the rate of doing work. It is also defined as the rate at which heat energy is given out by a source. For example, the heat energy delivered per second by a gas burner is its power. This power is measured in watts (W). One watt is therefore defined as one joule per second (J/s or Js-1). Other larger units are kilowatt (KW) and megawatt (MW). Sources of heat energy are the sun, fuels such as coal, gas, oil and electricity.

3.2 Heat Capacity

You would have observed that a source of heat will transfer its heat energy to another body. The source is usually at a high temperature while the other body being heated is at a lower temperature. When the source and the other body are in contact, the rise in temperature takes place in colder body.

Let t_1 °C be the initial temperature of the body and t_2 °C be the final temperature when Q joules of heat has been supplied.

Then the change in temperature,

$\Delta\theta = (t_2 - t_1)$°C

The amount of heat in joules that is capable of changing its temperature through 1°C is

Q.J/ Δθ

This amount of heat to change the temperature of the body is described as the heat capacity of the body. It is usually represented by the symbol H.

By definition, the heat (thermal) capacity (H) of a body, is the quantity heat (Q) in joules required to change its temperature by one degree (Celsius or one Kelvin).

$$\therefore \quad H = \frac{QJ}{\Delta\theta\ °C}$$

Where, $\Delta\theta = (t_2 - t_1)$

$$\therefore \quad H = \frac{QJ}{(t_2 - t_1)°C} \qquad \text{......................(4.1)}$$

Thus the unit of heat (thermal capacity is expressed in joules per Celsius or joules per Kelvin (JK-1 or J oC-1).

The values of H for different bodies are not the same. They vary from one body to another.

EXAMPLE 4.1
A metal container of heat capacity 200J $^{o}C^{-1}$ is heated from 15^{o}C to 45 ^{o}C. What is the total quantity of heat required to do so?

SOLUTION 4.1

Using Eq. (4.1)

$H = Q / \Delta\theta$

$$\therefore \quad Q = H\Delta\theta$$

$$= H(t_2 - t_1)$$

Substituting the values, we get

$$= 200\ J/^{\circ}C \times (45 - 15)^{\circ}C$$

$$= 200 \times 30J$$

$$Q = 6000J$$

$$Q = 6KJ$$

4.3 Specific Heat Capacity

If there are different masses of a substance m1, m2 and m3, it will be observed that to raise their temperatures through 1°C each, they will require different quantities of heat energy Q1, Q2 and Q3. Experiments have shown that the quantities of heat (Q) required to change their temperature through 1°C is proportional to the corresponding masses (m).

$\therefore Q \propto m$ .... (4.2)

However, if we fix the mass of the substance to 1kg we transfer various quantities of heat Q to it, there will be various corresponding changes in temperature $\Delta\theta$. Hence we can write

$Q \alpha \Delta\theta$ .... (4.3)

Combining these two factors, we get

$Q \alpha m\Delta\theta$

Or $Q = Cm\Delta\theta$ .... (4.4)

Where C is a constant of proportionality known as the specific heat capacity of the substance

$\therefore C = Q/ m\Delta\theta$

The specific heat capacity of a substance is therefore defined as the amount of heat Q (in joules) required to raise the temperature of 1kg mass of substance through unit degree (1°C or 1°K).

The unit of C is J/kg °C or or $Jkg^{-1}K^{-1}$. The value of C differs from one substance to another.

The values of specific heat capacity for some common substances are given in Table 4.1 below.

Table 4.1: Specific Heat Capacity for Some Substances

Substance	Specific heat capacity in $Jkg^{-1}°C^{-1}$
Iron	460
Copper	400
Lead	120
Aluminum	800
Water	4200

EXAMPLE 4.2

How much heat is needed to bring 10g of water from 50°C to boiling point? (Specific heat capacity of water = 4200 J/kg °C)?

SOLUTION 4.2

Using Eq. 4.4 Q = mCΔθ

= mC (t2 - t1)

Substituting the values, in the Eq. 4.4 we get,

= 10g/1000kg x 4200J/kg °C x (100 – 50) °C

Q = 2100J

= 2.1KJ

4.3.1 Simple Method of Mixtures

In this section we shall consider exchange of heat between two bodies in such a way that one body is at a high temperature and the other is at a low temperature. In the simple method of mixtures, we are simply looking at hot and cold substances being mixed without considering the container in which they are being mixed. The principle of conservation of heat energy is being observed very closely. Here, very briefly, we will discuss the principle of conservation of heat energy.

This principle states that ***"the heat lost by a hot body is equal to the heat gained by the cold body in any system provided there is no heat exchange between the substances involved and their surrounding"***

In a laboratory, use the calorimeter as the container with which you observe exchange of heat between two substances, keeping them usually at different temperatures. The cold body is usually in form of water or any liquid and the hot body could be a solid body or liquid at a higher temperature

Let illustrate this principle with this example,

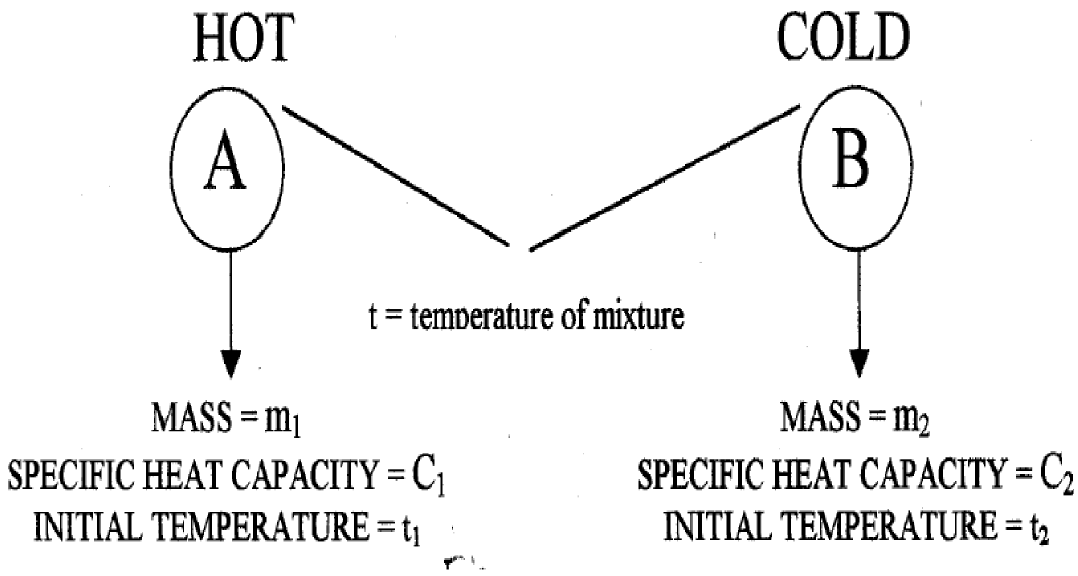

Fig. 4.1

If body A is the hot body at temperature t_1 and B is the cold body at temperature t_2, A and B are then mixed up to give a final temperature of mixture t. Let us see then what has happened?

(1) The hot body has lost some heat to the cold body B. The heat lost can be find out.

Let Q_1 be the amount of heat

$Q_1 = m_1c_1\Delta\theta_1$

$\therefore$ $Q1 = m_1c_1(t_1 - t)$

Or = $Q_1 = -m_1c_1(t - t_1)$ .... (4.5)

(2) The cold body B has gained some heat. The heat gained is,
Let Q_2 be the amount of heat gained.

$\therefore$ $Q_2 = m_2c_2\Delta\theta_2$

$Q2 = m_2c_2(t - t_2)$ .... (4.6)

(3) How do you relate Q_1 and Q_2? We relate them together by suing the principle of conservation of heat energy, which says that

"In any heat exchange provided heat is not lost to or gained from the surrounding."

Heat lost = Heat gained

$\therefore$ $Q_1 = Q_2$

$\therefore$ $m_1c_1\Delta\theta_1 = m_2c_2\Delta\theta_2$

$\therefore$ $m_1c_1(t_1 - t) = m_2c_2 (t - t_2)$ .... (4.7)