Heat

Heat can be defined as energy in transit. Heat can flow from a body or to a body. If a body is at a constant temperature, it has both mechanical and thermal energy due to the molecular agitation and it is not possible to separate them. Heat is a form of energy which flows from higher temperature to lower temperature by conduction, convection and radiation process. Heat is a form of energy which produces the sensation of hotness or coldness of a body.

Temperature

Temperature of a system can we define as the property that determine whether or not the body is in thermal equilibrium with the neighbouring system. If a number of systems are in thermal equilibrium, this common property of the system can be represented by a single numerical value called the temperature. It means that if two systems and not in thermal equilibriums, they are at different temperature.

Thermometry

The branch of heat relating to the measurement of temperature of a body is called thermometry.

Distinction between heat and temperature

Heat and temperature do not bear same meaning. The differences are stated below;

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2. Heat is the cause and temperature is the effect.

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2. Heat is the cause and temperature is the effect.

3. When a body absorbs heat its temperature increases and when the body gives up heat its temperature decreases.

4. Two bodies at the same temperature may have different amount of heat. Similarly, two bodies containing equal amount of heat does not mean equality in temperature in them.

5. Transfer of heat from one body to another body depends on the temperature difference.

6. The instrument for measuring heat is called calorimeter and the instrument for measuring temperature is called thermometer.

7. Unit of heat is Joule and the unit of temperature is °C or °K or °F.

8. Heat is proportional to the total energy of the molecules in the body; but temperature is proportional to the average kinetic energy of the molecule.

Thermometers:

The instrument with the help of which we may conveniently record temperature is called thermometers. The following types of thermometers are in common use:-

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i) **Liquid thermometer:** They are based on the expansion of liquids, such as mercury. Alcohol, etc.

ii) **Gas thermometer:** They work on the thermal expansion of gases like hydrogen, air, etc. These are more sensitive than liquid thermometers.

iii) **Resistance thermometer:** the electrical resistance of metals varies with temperature and this property of metals is used for measuring temperature.

temperature can be determined.

Different scale of temperature

The three common temperature scales in use today are the Fahrenheit, Celsius, and Kelvin scales.

Fahrenheit Scale

180

The **Fahrenheit** temperature scale is based on 32 °F for the freezing point of water and 212 °F for the boiling point of water, with the interval between the two being divided into 180 parts.

Celsius Scale

The **Celsius** temperature scale is based on 0 °C for the freezing point and 100 °C for the boiling point of water, with the interval between the two being divided into 100 parts.

The Kelvin scale

The solid, liquid, and gaseous phases of water can exist in equilibrium at 273.16 °C (the triple point temperature). The **Kelvin** is defined as 1/273.16 of the triple point temperature. This makes one kelvin the same size as one Celsius degree.

On the Kelvin scale, 0 K represents absolute zero, the temperature at which the molecules of a substance have their lowest possible energy.

Many physical laws and formulas can be expressed more simply by using the Kelvin scale. Accordingly, the Kelvin scale has become the international standard for scientific temperature measurement.

Relation among different scales of temperature

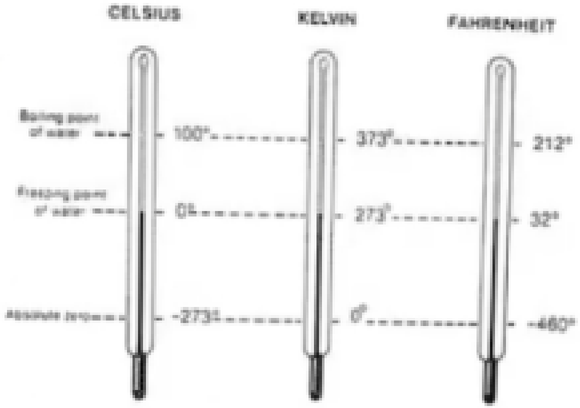
There is a relation between different scales of temperature. By this relation temperature in one scale can be converted into another scale. The relation between different scales is shown below:

Table for different scale of temperature

Name of the scale	Symbol	Lower fixed point	Upper fixed point	Fundamental interval
Celsius	C	0°	100°	100
Farenheit	F	32°	212°	180
Kelvin	T	273°	373°	100

Consider a thermometer. Let its lower and upper fixed point be A and B respectively. Let three thermometers, calibrated respectively in Celsius, Farenheit and Kelvin are taken. Suppose point

P reads C in the Celsius scale, F on the Farenheit scale and K on the Kelvin scale. The lower fixed point A coincides in the three thermometers and this point is 0°C, 32°F and 273°K in the three scales respectively.



The upper fixed point B also coincides in the three thermometers and the point corresponds to 100°C, 212°F and 373°K in the three scales [figure].

Now we get,

$$\frac{PA}{BA} = \frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{K-273}{373-273}$$

$$or,\ \frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$$

Math-1:

Room temperature" is generally defined in physics to be 25 °C.

(a) What is room temperature in °F? (b) What is it in K?

Solution

To convert from °C to °F, use the equation

$$\frac{C}{5} = \frac{F-32}{9}$$

$$F = \frac{9C}{5} + 32$$

$$F = \frac{9\times 25}{5} + 32 = 77^0 F$$

Similarly,

$$\frac{C}{5} = \frac{K-273}{5}$$

$$k = 273 + C$$

$$K = 273 + 25 = 298K$$

Math-2:

The boiling point of water is 100°C. What temperature does water boil at in the Fahrenheit scale?

Answer:

A Celsius temperature is given. To convert it to the Fahrenheit scale, use the formula at the left.

Fig: Seeback Effect

Expansion of solid

Solid can be divided into two categories

1. Isotropic and
2. anisotropic

Isotropic: Metals glasses and some regular systems of Crystal came under isotropic solid substance. These substances have the same properties in all directions and hence have the same coefficient of expansion in all directions.

Anisotropic: There are certain irregular crystals which when heated expand in one direction and contract in a perpendicular direction. Hence the coefficient of expansion is different in different directions. They are called anisotropic bodies.

Coefficient of linear expansion: Expansion in length is called linear expansion. As different bodies expand to different extents for the same rise of temperature, the property of linear expansion is denoted by a term called coefficient of linear expansion. The coefficient of linear expansion of a body designated as α.

If L_1 and L_2 be the length of a rod at temperature t_1^0C and t_2^0C then α the coefficient of linear expansion of the material is given by.

$$\alpha = \frac{L_2 - L_1}{L_1(t_2 - t_1)}$$

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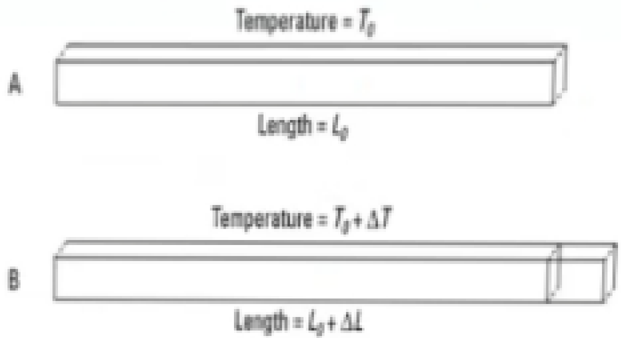
$$L_2 = L_1[1 + \alpha(t_2 - t_1)]$$



Coefficient of Superficial expansion:

It is defined as the increase in area per unit area per unit degree rise of temperature. If A_1 and A_2 are the areas of a solid at temperature t_1 and t_2 then β the coefficient of superficial expansion is given by the relation,

$$\beta = \frac{A_2 - A_1}{A_1(t_2 - t_1)}$$

$$A_2 = A_1[1 + \beta(t_2 - t_1)]$$

$$V_1(t_2 - t_1)$$

$$V_2 = V_1[1 + \gamma(t_2 - t_1)]$$

Relation between α and β:

Consider a square plate of side L_0 at 0^0C and L_t at t^0C. Let the area of the plate be A_0 at 0^0C and A_t at t^0C. Then,

$$L_t = L_0(1 + \alpha t) \quad \text{.................(i)}$$

$$A_0 = L_0^2 \quad \text{.....................(ii)}$$

$$A_t = L_t^2 \quad \text{.....................(iii)}$$

And

$$A_t = A_0(1 + \beta t) \quad \text{.................(iv)}$$

$$L_t^2 = L_0^2(1 + \beta t) \quad \text{.................(v)}$$

Substituting the value of L_t from *eq^n (i)* in *eq^n(v)*

$$L_0^2(1 + \alpha t)^2 = L_0^2(1 + \beta t)$$

$$\Rightarrow 1 + 2\alpha t + \alpha^2 t^2 = 1 + \beta t$$

Neglecting the term $\alpha^2 t^2$

$$2\alpha t = \beta t$$

$$\therefore \beta = 2\alpha$$

$\therefore \beta = 2\alpha$

Thus the superficial expansion of a substance is approximately twice of linear expansion.

Relation between α and γ:

Consider a cube of side L_0 at 0^0C and L_t at t^0C. Let the volume of the cube be V_0 at 0^0C and V_t at t^0C. Then,

$$L_t = L_0(1 + \alpha t) \text{ ....(i)}$$

$$V_0 = L_0^3 \text{ ....(ii)}$$

$$V_t = L_t^3 \text{ ....(iii)}$$

And

$$V_t = V_0(1 + \gamma t) \text{ ....(iv)}$$

$$L_t^3 = L_0^3(1 + \gamma t) \text{ ....(v)}$$

Substituting the value of L_t from eq^n (i) in eq^n(v)

$$L_0^3(1+\alpha t)^3 = L_0^3(1+\gamma t)$$

$$\Rightarrow 1 + 3\alpha t + 3\alpha^2 t^2 + \alpha^3 t^3 = 1 + \gamma t$$

Neglecting the higher power of α

$$3\alpha t = \gamma t$$

$$\therefore \gamma = 3\alpha$$

Thus the coefficient of cubical expansion approximately three times of its coefficient of linear expansion. As a close approximation the ratio between the three coefficients is

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

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Expansion of liquid

When a liquid is heated, its volume changes. Liquid have no shape of their own but conform to the shape of the containing vessel. When a liquid is heated, the containing vessel also expands and hence the measured increase in volume of the liquid is the apparent increase in volume. The real increase in volume of the liquid is equal to the sum of the apparent increase in volume of the liquid and the increase in volume of the containing vessel. Thus a liquid has two coefficients of expansion.

i) Coefficient of apparent expansion
ii) Coefficient of real expansion

Apparent expansion of liquid γ_a

The coefficient of apparent expansion of liquid is defined as the apparent increase in volume per unit volume with degree rise in temperature when the liquid is heated in a vessel that expands on heating.

Real expansion of liquid γ_r

The coefficient of real expansion of a liquid is defined as the actual increase in volume per unit volume per unit is a rise in temperature.

Relation Between γ_a and γ_r :

Newton's law of cooling

Newton's law of cooling states that the rate of loss of heat of a body is directly proportional to the difference of temperature of the body and the surrounding. The law holds good only for small difference of temperature. Also, the loss of heat by radiation depends upon the nature of the surface of the body and area of the exposed surface.

$$\frac{dH}{dt} \propto (\theta - \theta_0)$$

$$or, -\frac{dH}{dt} = k(\theta - \theta_0)$$

Specific heat

It is defined as the quantity of heat required to raise the temperature of unit mass of a substance through one degree.

$$s = \frac{H}{m\Delta\theta}$$

Thermal capacity

It is the quantity of heat required to rise the temperature of the whole of the substance through 1^0C.

Gas has two specific heat

i) specific heat at constant volume (C_V)

ii) specific heat at constant pressure (C_P)

$C_p > C_V$

Relation between Cp and Cv:

Consider one gram of a gas at a pressure P, volume V and temperature T. Heat is supplied to the gas to raise its temperature through dT. As the pressure has to remain constant,
Work done,

$$W = PW = P \times A \times x = P \times dV;$$

From the gas equation

$$PV = rT$$

Differentiating

$$PdV + VdP = rdT$$
$$\text{But } dP = 0$$
$$PdV = rdT$$

Work done in heat units= $\frac{r.dT}{J}$calories

Heat Supplied= $1 \times C_p \times dT = 1 \times C_v dT + \frac{rdT}{J}$

$or, C_p - C_v = \frac{r}{J}$

Where, r is the gas constant for 1 gram of a gas. If C_P and C_V represent gram molecular specific heat then,

$C_p - C_v = \frac{R}{J}$

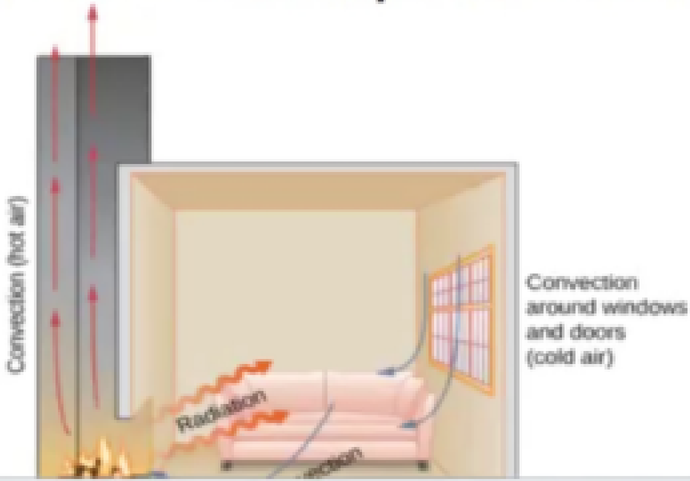
Where, R is the universal gas constant.

heat transfer that it is hard to imagine a situation where no heat transfer occurs. Yet every heat transfer takes place by only three methods:

1. **Conduction** is heat transfer through stationary matter by physical contact. (The matter is stationary on a macroscopic scale—we know that thermal motion of the atoms and molecules occurs at any temperature above absolute zero.) Heat transferred from the burner of a stove through the bottom of a pan to food in the pan is transferred by conduction.

2. **Convection** is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced-air furnace and in weather systems, for example.

3. Heat transfer by **radiation** occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of Earth by the Sun. A less obvious example is thermal radiation from the human body.



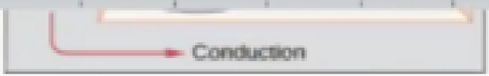


Figure: In a fireplace, heat transfer occurs by all three methods: conduction, convection, and radiation. Radiation is responsible for most of the heat transferred into the room. Heat transfer also occurs through conduction into the room, but much slower. Heat transfer by convection also occurs through cold air entering the room around windows and hot air leaving the room by rising up the chimney.

Math:

The main span of San Francisco's Golden Gate Bridge is 1275 m long at its coldest. The bridge is exposed to temperatures ranging from –15°C to 40°C. What is its change in length between these temperatures? Assume that the bridge is made entirely of steel.

Math:

An iron rod of length 50 cm is joined at .an end to an aluminium rod of length 100 cm. All measurements refer to 20°C. Find the length of the composite system at 100°C and its average coefficient of linear expansion. The coefficient of linear expansion of iron and aluminium are 12 x 10^{-6} $^{0}C^{-1}$ and 24 x 10 -6 0c-l respectively.