CHAPTER EIGHT
TEMPERATURE

Temperature and the Zeroth Law of Thermodynamics

Thermal equilibrium is a situation in which two objects would not exchange energy by heat or electromagnatic radiation if they are placed in thermal contact.

Zeroth law of thermodynamics (The law of equilibrium): If objects **A** and **B** are separately in the thermal equilibrium with a third object **C**, then **A** and **B** in thermal equilibrium with each other.

Temperature: The property that determines whether an object is in thermal equilibrium with other objects.

Thermometers are devices that are used to measure the temperature of a system. A common thermometr cosists of a mass of liquid usually mercury or alcohol that expands into a glass capillary tube when heated.

The constant-volume Gas thermometer and the absolute temperature scale

The physical change exploited in this device is the variation of pressure of a fixed volume of gas with temperature.

$$\mathbf{T = T_c + 273.15}$$

T = absolute temperature & T_c = celsius temperature

** kelvin* is defined to be (1/273.16) of the difference between absolute zero and the temperature of the triple point of water.

The celsius, Fahrenheit and Kelvin Temperature

A common temperature scale use in the united states is the (Fahrenheit scal).

$$\mathbf{T_f = (9/5)\, T_c + 32\ °F}$$

$$\mathbf{\Delta T_c = \Delta T = (5/9)\, T_f}$$

Example 1: A pan of water is heated from (25 °c) to (80 °c). What is the change in its temperature on the kelvin scale and on the fahrenheit scale?

Solution: $\mathbf{\Delta T = \Delta T_c = 80\ °c - 25\ °c = 55\ °c}$

$$\mathbf{\Delta T_f = (9/5)\, \Delta T_c = (9/5)*55\ °c = 99\ °F}$$

Thermal Expansion of Solids and Liquids

Thermal expansion: is a consequence of the change in the average separation between the atoms in an object.

* The average coefficient of linear expansion (α):

$\boldsymbol{\alpha = (\Delta L/L_i) / \Delta T}$

$\boldsymbol{\Delta L = \alpha . L_i . \Delta T \Longrightarrow L_f - L_i = \alpha . L_i (T_f - T_i)}$

***** positive value of (**α**) indicating an increase in length with increasing temperature.

* The change in volume (**Δv**)

$\boldsymbol{\Delta v = \beta . v_i . \Delta T}$ (**β** = average coefficient of volume expansion)

For solid: $\boldsymbol{\beta = 3\alpha}$

$\boldsymbol{\Delta v = 3\alpha . v_i . \Delta T}$

* The change in Area (**ΔA**)

$\boldsymbol{\Delta A = 2\alpha . A_i . \Delta T}$ (**β** = average coefficient of volume expansion)

Example 2: A segment of steel rail road track has a length of (30 m) when the temperature is (0.0 °c).

(a) what it's length when the temperature is (40 °c)? Take ($\boldsymbol{\alpha}$ = $11*10^{-6}$/°c)

(b) suppose the ends of the rail are rigidly clamped at (0.0 °c) so that the expansion is prevented. What is the thermal stress setup in the rail if it's temperature is raised to (40 °c)?

Solution:

(a) $\boldsymbol{\Delta L = \alpha . L_i . \Delta T}$ = $(11*10^{-6}/°c)(30m)(40°c) = 0.013m$

$L_f = 30.013$ m

(b) Tensile stress = **F/A = ϒ(ΔL/Li)**

ϒ = young's modulus for solid

$ϒ_{steel} = 20*10^{10}\ N/mm^2 = 200G\ N/mm^2 = 200$ Gpa

$F/A = (20*10^{10}\ N/mm^2)(0.013m/30m) = 8.7*10^7 N/mm^2 = 87$ Mpa

The unusual behavior of water

Liquids generally in crease in volume with increasing temperature and have average coeficients of volume expansion about (10) times than those of solids. Cold water is an exception to this rule.

1- As temperature increases from (0 °c to 4 °c) water contracts and thus its density increases.

2- Above (4 °c), water expands with increasing temperature and so its density decrease. Thus the density of water reaches a maximum value of (1 gm/cm^3 at 4 °c).

***** We can use unusual thermal-expantion behavior of water to explain why a pond begins freezing at the surface rather than at the bottom.