

### Sem-III - Thermal Physics II

(Instructor: AKB, Department of Physics, Asutosh College)

Assignment I: 0<sup>th</sup> law & Thermodynamic Systems

Submission due date: 09/08/2019

- Q.1)** (a) The equation of state of an ideal gas is  $PV = RT$ . Show that  $\beta = T^{-1}$  and  $\kappa = P^{-1}$ .  
(b) The equation of state of a real gas at moderate pressure is  $P(V - b) = RT$ . Show that

$$\beta = T^{-1}/\{1 + bP/RT\}, \text{ and } \kappa = P^{-1}/\{1 + bP/RT\}.$$

- (c) The equation of state of a real gas at moderate pressure is  $PV = RT(1 + B/V)$  with  $B = B(T)$ . Show that

$$\beta = T^{-1}\{V + B + T(dB/dT)\}/\{V + 2B\}, \text{ and } \kappa = P^{-1}/\{1 + BRT/PV^2\}.$$

- Q.2)** Systems  $A, B$ , and  $C$  are gases with coordinates  $(P, V), (P', V'), (P'', V'')$ . When  $A$  and  $C$  are in thermal equilibrium, the equation

$$PV - nbP - P''V'' = 0$$

is found to be satisfied. When  $B$  and  $C$  are in thermal equilibrium, the relation

$$P'V' - P''V'' + \frac{nB'P''V''}{V'} = 0$$

- holds. The symbols  $n, b$  and  $B'$  are constants. (a) What are the three functions which are equal to one another at thermal equilibrium and each of which is equal to an empirical temperature  $T$ ?  
(b) What is the relation expressing thermal equilibrium between  $A$  and  $B$ ?

- Q.3)** A liquid is irregularly stirred in a well-insulated container and thereby undergoes a rise in temperature. If we regard the liquid as the system, (a) Has heat been transferred? (b) Has work been done? (c) What is the sign of  $\Delta U$ ?

- Q.4)** Systems  $A$  and  $B$  are paramagnetic salts with coordinates  $\mathcal{H}, M$  and  $\mathcal{H}', M'$  respectively. System  $C$  is a gas with coordinates  $P, V$ . When  $A$  and  $C$  are in thermal equilibrium, the equation

$$4\pi nRC_c\mathcal{H} - MPV = 0$$

is found to hold. When  $B$  and  $C$  are in thermal equilibrium, we get

$$nR\Theta M' + 4\pi nRC'_c\mathcal{H}' - M'PV = 0,$$

where  $n, R, C_c, C'_c$  and  $\Theta$  are constants. (a) What are the three functions that are equal to one another at thermal equilibrium? (b) Set each of these functions equal to the ideal-gas temperature  $T$  and see whether any of these equations are equation of state for paramagnetic substance (Curie's law  $M = C'_c \frac{\mathcal{H}}{T}$ ).

- Q.5)** The equation of state of an ideal elastic substance is  $\mathfrak{S} = KT(\frac{L}{L_0} - \frac{L_0^2}{L^2})$  where  $K$  is a constant and zero tension value of  $L = L_0(T)$ . (a) Show that the isothermal Young's modulus  $Y$  and at zero tension  $Y_0$  are given by

$$Y = \frac{kT}{A} \left( \frac{L}{L_0} + \frac{2L_0^2}{L^2} \right), \quad Y_0 = \frac{3KT}{A}.$$

(b) Show that the linear expansivity is given by

$$\alpha = \alpha_0 - \frac{\mathfrak{S}}{AYT} = \alpha_0 - \frac{L^3/L_0^3 - 1}{T(L^3/L_0^3 + 2)},$$

where  $\alpha_0 = \frac{1}{L_0} \frac{dL_0}{dT}$  is the linear expansivity at zero tension.