Roll No. ☐☐☐☐☐☐☐☐☐☐☐☐ **Total No. of Pages : 02**

Total No. of Questions : 08

M.Tech. (ME) (2017 Onwards) (Sem.–1)

ADVANCED THERMODYNAMICS

Subject Code : MTME-105

M.Code : 74719

Time : 3 Hrs. **Max. Marks : 100**

INSTRUCTIONS TO CANDIDATES :

1. **Attempt any FIVE questions in all, out of EIGHT questions.**
2. **Each question carry TWENTY marks.**

1. a) What is physical interpretation of c_v and c_p ?

   b) Consider a cup full of coffee placed in room air. If the pressure and entropy are maintained constant within the rigid room, in practice how can there be a heat loss?

2. A steel casting weighing 20 kg is removed from a furnace at a temperature of 800 ºC and heat treated by quenching in a bath containing 500 kg water at 20ºC. Calculate the change in availability of the universe due to this operation. The specific heat of the water is 4.18 KJ/kg K, and that of steel is 0.42 KJ/kg K. Assume that the bath of water is rigid and perfectly insulated from the surroundings after the casting has been dropped in, and take the datum temperature and pressure as 20ºC and 1 bar respectively.

3. A dry gas analysis of the gas exhaled by a human lung is as follows – O_2 : 16.5% and CO_2:3.1%. Assume the ''fuel'' burned by humans is characterized by the chemical formula CH_x and is completely burned. Determine the values of ''x'' and (A:F).

4. a) The Joule Thomson effect can be depicted through a porous plug experiment that illustrates that the enthalpy remains constant during a throttling process. In the experiment a cylinder is divided into two adiabatic variable volume chambers A and B by a rigid porous material placed between them. The chamber pressures are maintained constant by adjusting the volume. Freon vapor with an initial volume $V_{A,1}$, pressure $P_{A,1}$ and energy $U_{A,1}$ is present in chamber A. The vapors penetrate through the porous wall to reach chamber B. The final volume of chamber A is zero. Determine the work done by the gas in chamber B, and the work done on chamber A. Apply the First Law for the combined system A and B and show that the enthalpy in the combined system is constant.

   b) Show that generally real gases deliver a smaller amount of work as compared to an ideal gas during isothermal expansion for a (a) closed system from volume v_1 to v_2, and (b) an open system from pressure P_1 to P_2.

5. a) Obtain a relation for ds for an ideal gas. Using the criterion for an exact differential, show that for this gas c_v is only a function of temperature.

b) A substance undergoes an adiabatic and reversible process. Obtain an expression for $(\partial T/\partial v)_s$ in terms of c_V, β_P, β_T and T. What is the value of $(\partial T/\partial v)_s$ for copper, given that $\beta_P = 5 \times 10^{-5}\ K^{-1}$, $\beta^T = 8.7 \times 10^{-7}\ bar^{-1}$, $c = c_v = 0.386\ kJ\ kg^{-1}\ K^{-1}$, $v = 1.36 \times 10^{-4}\ m^3\ kg^{-1}$, and the temperature is 25°C? What is the temperature rise if $dv = -8.106 \times 10^{-7}\ m^3\ kg^{-1}$?

6. Find the maximum work deliverable in a fuel cell by 1 kmole of H_2 with O_2 if it is isothermally reacted at 25ºC and 1 bar to produce liquid water. Both reactants enter the cell separately. Determine the maximum voltage developed by the fuel cell. Consider also the scenario for the reaction of a stoichiometric amount of H_2 with O_2. What is the maximum possible fuel cell efficiency? Assume that $\Delta h_c = 285830\ kJ\ kmole^{-1}$.

7. Show that the Joule-Thomson coefficient, μ, is given by :

$$\mu = 1/c_p\ (T(\partial v/\partial T)_p - v)$$

Hence or otherwise show that the inversion temperature (T_i) is :

$$T_i = (\partial T/\partial v)_p\ v$$

8. a) A thermal conductor with constant thermal and electrical conductivities, k and λ respectively, connects two reservoirs at different temperatures and also carries an electrical current of density, J_1. Show that the temperature distribution for one-dimensional flows is given by :

$$\frac{d^2T}{dx^2} - \frac{J_1\sigma}{k}\frac{dT}{dx} + \frac{J_1^2}{\lambda} = 0$$

Where σ is the Thomson coefficient of the wire.

b) If a fluid, consisting of a single component, is contained in two containers at different temperatures, show that the difference in pressure between the two containers is given by

$$\frac{dp}{dT} = \frac{h - u^*}{vT}$$

where h = specific enthalpy of the fluid at temperature T,

u^* = the energy transported when there is no heat flow through thermal conduction,

v = specific volume,

T = temperature.

NOTE : Disclosure of Identity by writing Mobile No. or Making of passing request on any page of Answer Sheet will lead to UMC against the Student.