BENGAL ENGINEERING AND SCIENCE UNIVERSITY, SHIBPUR

M.E. (Mech) 1st Semester Final Examination, 2011

ADVANCED ENGINEERING THERMODYNAMICS (ME-906)

Branch: Mechanical Engineering

Time: 3 Hrs. Full Marks: 70

Answer any **five questions.**

Marks are indicated at the right hand margin for each question.

1. **(a)** A reversible heat engine in a satellite operates between a hot reservoir at temperature T_1 and a radiating panel at T_2. Radiation from the panel is proportional to its area and to T^4_2. For a given work output and value of T_1 show that the area of the panel will be minimum when $\frac{T_2}{T_1} = 0.75$.

   Determine the minimum area of the panel for an output of 1 kW if the constant of proportionality is 5.67×10^{-8} W/m^{2}K^4 and T_1 is 1000 K. (7)

   (b) A body of constant heat capacity C_p and at a temperature T_i is put in contact with a reservoir at a higher temperature T_f. The pressure remains constant while the body comes to equilibrium with the reservoir. Show that the entropy change of the universe is equal to $C_p\left[\frac{T_i - T_f}{T_f} - \ln\left(1+\frac{T_i - T_f}{T_f}\right)\right]$.

   Also prove that this entropy change is positive.

   Given $\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + ...upto\ \alpha$ for x<1 (7)

2. **(a)** Calculate the decrease in available energy when 25 kg of water at 95^{0}C is mixed with 35 kg of water at 35^{0}C, the pressure being taken as constant and the temperature of the surrounding being 15^{0}C. Take c_p of water = 4.2 kJ/kg K. (7)

   (b) A hot gas of mass m_g and specific heat c_{pg} is available at temperature T. If the environmental temperature is T_0, show that the exergy or available energy of the gas is given by

$$AE = m_g c_{pg}\left[(T - T_0) - T_0 \ln\frac{T}{T_0}\right]$$ (7)

3. (a) What do you mean by virial co-efficient type of equation of state? Express van der Waals equation of state in virial form. How Boyle temperature can be determined from the above equation? (7)

(b) Show that the Gibbs function of a mixture of ideal gases at temperature T and Pressure P is given by $G = \overline{R}T\sum n_k(\phi_k + \ln P + \ln x_k)$, where the symbols have their meanings. Also state the significance of Gibbs function. (7)

4. (a) Derive the following relations for the difference in heat capacities c_p and c_v of a substance:

$$c_p - c_v = -\left(\frac{\partial v}{\partial T}\right)_P^2 \left(\frac{\partial P}{\partial v}\right)_T = \frac{vT\beta^2}{\alpha}$$

where α and β are isothermal compressibility and volume expansivity respectively. The other symbols have their usual meanings

What conclusions can be drawn from the above relations? Also show that for a perfect gas the above expression reduces to $c_p - c_v = R$. (9)

(b) Determine the difference between c_p and c_v for water at 300 K for which coefficient of volume expansion $\beta = 2\times10^{-4}\ K^{-1}$, isothermal compressibility $\alpha = 4.85\times10^{-4}\ MPa^{-1}$ and specific volume $v = 0.001003\ m^3/kg$. (5)

5. (a) What do you mean by degree of reaction of a chemical reaction? State the importance of van't Hoff equation in reactive system. If K_1 and K_2 be the equilibrium constants at temperatures T_1 and T_2 respectively, then using van't Hoff equation show that the heat of reaction is given by

$$\Delta H = 19.148 \frac{T_1 T_2}{T_1 - T_2} \log \frac{K_1}{K_2} \text{ kJ/kg mol} \quad (8)$$

(b) Starting with n_0 moles of water vapour which dissociates according to the equation $H_2O \Leftrightarrow H_2 + \frac{1}{2}O_2$, show that at equilibrium

$$K = \frac{\varepsilon_e^{3/2}}{(2+\varepsilon_e)^{1/2}(1-\varepsilon_e)} \cdot p^{1/2} \quad (6)$$

6. Write short notes (any three): (14/3×3=14)

(a) Helmholtz function and Gibbs function

(b) Significance of Maxwell's Equations in Thermodynamics

(c) Clausius- Clapeyron Equation

(d) Second Law Efficiency