Code No: R09220804 **R09** **Set No. 2**

II B.Tech II Semester Examinations,APRIL 2011
CHEMICAL ENGINEERING THERMODYNAMICS
Common to Chemical Engineering, Computer Science And Engineering

Time: 3 hours **Max Marks: 75**

Answer any FIVE Questions
All Questions carry equal marks

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1. A central power plant, rated at 800,000kW, generates steam at 585 K and discards heat to a river at 295 K. If the thermal efficiency of the plant is 70% of the maximum possible value, how much heat is discarded to the river at rated power? [15]

2. One mole of an ideal gas, Cp = (7/2)R and Cv = (5/2)R, is compressed adiabatically in a piston/cylinder device from 2 bar and 25^0C to 7 bar. The process is irreversible and requires 35% more work than a reversible, adiabatic compression from the same initial state to the same final pressure. What is the entropy change of the gas? [15]

3. Liquid water enters an adiabatic hydro turbine at 5 atm and 288.15 K, and exhausts at 1 atm. Estimate the power output of the turbine in J/ kg of water if its efficiency is $\eta = 0.55$. What is the outlet temperature of the water? Assume water to be an incompressible liquid. [15]

4. If H = H (T, P) show that
   $dH = Cp\,dT + \left[V - T\left(\frac{\partial V}{\partial T}\right)\right] dP$ [15]

5. (a) A balloon which is initially collapsed and flat is slowly filled with hydrogen at 100 kPa so as to form it into a sphere of radius 1m. Determine the work done by the gas in the balloon during the filling process.
   (b) Discuss about kinetic & potential energy. [9+6]

6. Describe about 'absorption refrigeration' using a neat schematic diagram. [15]

7. If a cylinder of volume 0.1m^3 is filled with 1.373 kg of ammonia at 1.95MPa, determine the temperature at which ammonia exists in the cylinder. Assume that ammonia obeys the Van der Waals equation of state. The van der waals constants a and b for ammonia are 422.54×10^{-3} Pa $(\text{m}^3/\text{mol}^2)^2$ and 37×10^{-6} m^3/mol respectively. [15]

8. A nonconducting container filled with 25 kg of water at 293.15 K is fitted with a stirrer, which is made to turn by gravity acting on a weight of mass 35 kg. The weight falls slowly through a distance of 5 m in driving the stirrer. Assuming that all work done on the weight is transferred to the water and that the local acceleration of gravity is 9.8 m/s^2, determine:
   (a) The amount of work done on the water.
   (b) The internal-energy change of the water.

(c) The final temperature of the water, for which $C_p = 4.18$ kJ/ kg ^{0}C. [15]

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1. (a) What pressure difference does a 10 m column of atmospheric air show? Density of air = 1.2 kg/m^3.
   (b) A manometer shows a pressure difference of 1 m of liquid mercury. Find ΔP in kPa. [8+7]

2. Define a thermodynamic diagram and discuss about different types of thermodynamic diagrams with neat sketch. [15]

3. Derive the first law of thermodynamics for steady-state steady flow process. Explain all the notations used. [15]

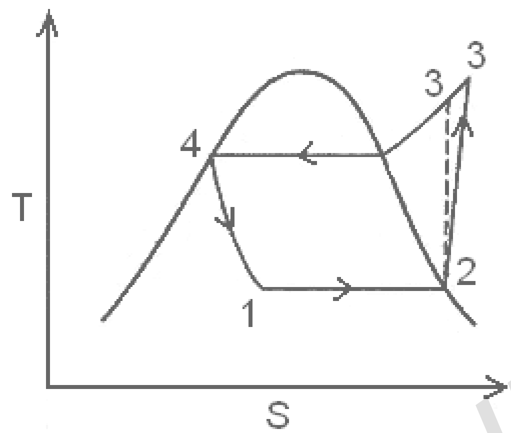
4. Discuss about the principles of conservation of energy for flow systems. [15]

5. The following heat engines produce power of 95 000 kW. Determine in each case the rates at which heat is absorbed from the hot reservoir and discarded to the cold reservoir.
   (a) A Carnot engine operates between heat reservoirs at 750 K and 300 K.
   (b) A practical engine operates between the same heat reservoirs but with a thermal efficiency $\eta = 0.35$. [15]

6. A 0.35-m^3 vessel is used to store liquid propane at its vapor pressure. Safety considerations dictate that at a temperature of 320 K the liquid must occupy no more than 80% of the total volume of the vessel. For these conditions, determine the mass of vapor and the mass of liquid in the vessel. At 320 K the vapor pressure of propane is 16.0 bar. [15]

7. How would the increase in entropy be used as a measure of the irreversibility of a process? [15]

8. A vapour-compression refrigeration system operates on the cycle of figure 1. The refrigerant is water. Given that the evaporation T = 277.15 K, the condensation T = 307.15 K, η (compressor) = 0.76, and the refrigeration rate = 1200 kW, determine the circulation rate of the refrigerant, the heat-transfer rate in the condenser, the power requirement, the coefficient of performance of the cycle, and the coefficient of performance of a Carnot refrigeration cycle operating between the same temperature levels. [15]



Vapor compression refrigeration cycle

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1. What is entropy? How the entropy change in an irreversible process determined? [15]

2. What are the different steps involved in Carnot refrigeration Cycle? Discuss with diagram. [15]

3. Explain the establishment of a thermodynamic temperature scale. [15]

4. A small adiabatic air compressor is used to pump air into a 20 m^3 insulated tank. The tank initially contains air at 298.15 K and 101.33 kPa, exactly the conditions at which air enters the compressor. The pumping process continues until the pressure in the tank reaches 1000 kPa. If the process is adiabatic and if compression is isentropic, what is the shaft work of the compressor? Assume air to be an ideal gas for which Cp = (7/2)R and Cv = (5/2)R. [15]

5. How do you estimate the residual properties (G^R, H^R and S^R) from virial equation of state? Explain. [15]

6. (a) Define work? Derive the equation for work and show that $W = -\int_{V_1}^{V_2} PdV$

   (b) Define 'molar volume' and 'specific volume'. [10+5]

7. Steam flows at steady state through a converging, insulated nozzle, 25 cm long and With an inlet diameter of 5 cm. At the nozzle entrance (state 1), the temperature and Pressure are 598.15 K and 700 kPa, and the velocity is 30 m/ s. At the nozzle exit (state 2), the steam temperature and pressure are 513.15 K and 350 kPa. Property values are:
   H1=3112.5 kJ/kg V1=388.61cm^3/g
   H2 = 2945.7 kJ /kg V2 = 667.75 cm^3 /g
   What is the velocity of the steam at the nozzle exit, and what is the exit diameter? [15]

8. A 0.4 kg mass of nitrogen at 27^{0}C is held in a vertical cylinder by a frictionless Piston. The weight of the piston makes the pressure of the nitrogen 0.35 bar higher than that of the surrounding atmosphere, which is at 1bar and 27^{0}C. Thus the nitrogen is initially at a pressure of 1.35 bar, and is in mechanical and thermal equilibrium with its surroundings. Consider the following sequence of processes:

   (a) The apparatus is immersed in an ice/water bath and is allowed to come to Equilibrium.
   (b) A variable force is slowly applied to the piston so that the nitrogen is compressed reversibly at the constant temperature of 0^{0}C until the gas volume reaches one-half the value at the end of step (a). At this point the piston is held in place by latches.
   (c) The apparatus is removed from the ice/water bath and comes to the thermal Equilibrium with the surrounding atmosphere at 27^{0}C.
   (d) The latches are removed and the apparatus is allowed to return to complete equilibrium with its surroundings.

   Sketch the entire cycle on PV diagram, and calculate Q, W, for the nitrogen for each step of the cycle. Nitrogen may be considered as an ideal gas for which $C_V = (5/2)R$ and $C_P = (7/2)R$. [15]

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1. (a) What is meant by a heat engine and what are its characteristics?
   (b) A reversible heat engine has an efficiency of 0.6 when it absorbs 400kJ of energy as heat from a reservoir at 537^0C. Calculate the sink temperature and energy rejected as heat to the sink. [6+9]
2. Discuss about Carnot refrigerator and derive equation for COP. [15]
3. (a) At what absolute temperature do the Celsius and Fahrenheit temperature scales give the same numerical value? What is the value?
   (b) Define the terms 'Pressure' and 'work'.
   (c) Discuss the concept of internal energy using joules experiment. [5+5+5]
4. (a) Write short notes on Van der waals equation of state.
   (b) Reported values for the virial coefficients of isoproponol vapour at 200^0C are: B = - 0.388 m^3/knoll, C = - 26×10^{-3} $m^6/kmol^2$
   Calculate V and Z for isoproponol vapour at 200^0C and 10 bar by Ideal gas equation. [8+7]
5. What is the entropy change of the gas, heated in a steady-flow process at approximately atmospheric pressure,
   (a) When 800 kJ is added to 10 mol of ethylene initially at 473.15 K?
   (b) When 2500 kJ is added to 15 mol of 1-butene initially at 533.15 K? [7+8]
6. An incompressible (ρ = constant) liquid flows steadily through a conduit of circular cross -section and increasing diameter. At location 1, the diameter is 2.5 cm and the velocity is 2 m/s; at location 2, the diameter is 5 cm.
   (a) What is the velocity at location 2?
   (b) What is the kinetic-energy change (J/ kg) of the fluid between locations 1 and 2? [15]
7. For an adiabatic compression process show that
   Ws (isentropic) = $C_pT_1[(P_2/P_1)^{R/Cp} - 1]$ [15]
8. Develop the property relations appropriate to the incompressible fluid, a model fluid for which both β and κ are zero. [15]

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