

II B.Tech II Semester Supplementary Examinations, Apr/May 2008
CHEMICAL ENGINEERING THERMODYNAMICS-I
(Chemical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
 All Questions carry equal marks

1. (a) Define eq^m and thermodynamic eq^m classify and illustrate different eq^m states of a system.
 (b) Explain zeroth law of thermodynamics. [10+6]
2. (a) Define internal energy. Name those energy which constitute Internal energy.
 (b) State the thermodynamic definition of work.
 (c) Show that $\left(\frac{\partial v}{\partial T}\right)_T = -\left(\frac{\partial s}{\partial p}\right)_T$ [4+4+8]
3. Steam enters a nozzle at a pressure of 7 bars and $205^\circ C$. Initial enthalpy being 2850 kJ/kg and leaves at a pressure of 1.5 bars. The initial velocity of steam at the entrance is 40 m/s and the exit velocity from the nozzle is 700 m/s. The mass flow rate through the nozzle is 1400 kg / h. The heat loss from the nozzle is 11705 kJ/h. Determine the final enthalpy of steam and the nozzle exit area, if the specific volume is $1.24 m^3/kg$. [16]
4. (a) Define specific heat, internal energy and enthalpy of an ideal gas.
 (b) Obtain an expression for the entropy change of an ideal gas. [6+10]
5. (a) Calculate Z (compressibility factor) and V for isopropanol vapour at $200^\circ C$ and 10 atm. using virial equation of state. Virial equation of state is given by:

$$Z = 1 + \frac{BP}{RT} \text{ where } B = \frac{RT_c}{P_c} (B^0 + \omega B^1)$$

$$T_c = 508.2^\circ K \quad P_c = 50 \text{ atm} \quad V_c = 220.4 \text{ cm}^3/g.mole \quad \omega = 0.7.$$
 (b) Write a short note on PVT Behaviour of pure substances [8+8]
6. A reversible engine absorbs 250 Kcal of heat at $260^\circ C$ and discards heat at $40^\circ C$, what is
 (a) the work output of the engine.
 (b) the heat rejected
 (c) the entropy change of system, surrounding and total change in entropy.
 (d) the efficiency of heat engine [4x4]
7. (a) Calculate the difference in entropy of 0.5kg of liquid water at $0^\circ C$ and $1 \times 10^5 \text{ N/m}^2$ pressure and 0.5kg of water vapor at $100^\circ C$ and 1(atm) pressure, the latent heat of vaporization at $100^\circ C$ is 530 kJ/kg.

(b) Define the 3rd law of thermodynamics. [10+6]

8. Suppose a Carnot refrigerator operating between -25°C and 40°C consumes 0.5 kW power. Determine the rate of energy removal (Q_L) from the cold body. If Carnot heat pump operating between the same reservoirs requires which rejects energy (Q_H) to the high temperature body at the same rate as the Carnot refrigerator is extracting from the cold body (Q_L). Calculate the power consumption. [16]

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1. (a) Define the term Thermodynamics. What are its applications?
(b) State the study of Thermodynamics with the view point of microscopic and macroscopic approach [8+8]
2. (a) A closed system contains coal. If coal is burnt, the temperature of system rises. What happens the energy content of the system? Discuss the above case in thermodynamic sense.
(b) Show that $\left(\frac{\partial T}{\partial V}\right)_s = -\left(\frac{\partial P}{\partial S}\right)_v$ [8+8]
3. Explain the application of steady flow energy equation to a turbine and a condenser. [16]
4. Two tanks A & B are connected by a valve. Tank A has a volume of 0.15 m^3 and contains steam at 250°C with a quality of 0.85. Tank B is evacuated. Now the valve is opened and both the tanks reach an equilibrium pressure of 5.2 bar while the temperature is maintained constant at 250°C . Determine the volume of tank B. [16]
5. (a) Find the specific volume of propane at a pressure of 7.5 MPa and a temperature of 450 K using generalized compressibility chart (chart should be given)
(b) Find the pressure of propane using generalized compressibility chart if the temperature and specific volume are 450 K and $0.006 \text{ m}^3/\text{kg}$ respectively.
(c) Find the temperature of propane using generalized compressibility chart if the specific volume and pressure are $0.006 \text{ m}^3/\text{kg}$ and 7.5 MPa respectively. [6+5+5]
6. (a) A reversible heat engine A absorbs energy from a reservoir at T_1 and rejects energy to a reservoir at T_2 . A second reversible engine B absorbs, the same amount of energy as rejected by the engine A, from the reservoir at T_2 and rejects the energy to a reservoir at T_3 . What is the relation between T_1 , T_2 and T_3 , if
 - i. The efficiencies of engines A and B are the same.
 - ii. The work delivered by the engines are the same.(b) Prove that the efficiency of carnot engine depends on temperature levels only. [10+6]
7. A refrigeration system requires 2.5 kW of power for a refrigeration rate of 6 kJ s^{-1} .

- (a) What is the coefficient of performance ?.
 - (b) How much heat is rejected in the condenser ?.
 - (c) If the rejection is at 40°C , what is the lowest temperature the system can possibly maintain ? [6+6+4]
8. (a) Explain Cloude's process for air liquefaction with neat sketch. Show it by T-S diagram.
- (b) Obtain the relation for the COP of an absorption-refrigeration process. [8+8]

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1. (a) Define and explain the terms temperature. Further, compare the various temperature scales.
(b) Define work and heat in thermodynamic sense and bring out the comparison between them. [8+8]
2. (a) A pressure gauge fitted to a steam boiler records a pressure of 34 bar. The vacuum gauge on the condenser indicates 0.94 bar. If the atmospheric pressure is 1 bar, calculate:
 - i. Absolute pressure in the boiler in Pa
 - ii. Absolute pressure in the condenser in Pa.(b) Show that $\left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$ [8+8]
3. In a vessel 10 kg of oxygen is heated in a reversible, non flow, constant volume process so that the pressure of oxygen is increased two times that of the initial value. The initial temperature is 20°C . Calculate
 - (a) the final temperature,
 - (b) the change in internal energy,
 - (c) the change in enthalpy and
 - (d) the heat transfer. Take $R = 0.259 \text{ kJ / kg K}$ and $C_v = 0.652 \text{ kJ / kg K}$ for oxygen.
4. (a) Differentiate between adiabatic and non-adiabatic process
(b) Calculate C_p and C_v of air if 0.46 kg of air at 179°C expands adiabatically to three times of its original volume. During this expansion process the temperature drops to 15.5°C . The work done by the air is 52.
(c) What is equation of state and explain any equation of state known to you. [6+5+5]
5. (a) Discuss briefly the virial expansion.
(b) In predicting pressures with an accuracy of 2%, a Vander Waals gas is treated as an ideal gas. Find the region of p-v-T surface in which the above approximation is valid. [8+8]
6. A reversible engine absorbs 250 Kcal of heat at 260°C and discards heat at 40°C , what is

- (a) the work output of the engine.
 (b) the heat rejected
 (c) the entropy change of system, surrounding and total change in entropy.
 (d) the efficiency of heat engine [4x4]

7. A refrigerated space is maintained at 10°F and cooling water is available at 70°F . The evaporator and condenser are of sufficient size that 10°F minimum temperature difference for heat transfer can be realized in each. The refrigeration capacity is $120,000(\text{Btu})/\text{hr}^{-1}$. The refrigerant is tetrafluoroethane, for which data are provided below.

$T(^{\circ}\text{F})$	$P(\text{psia})$	Liq.Vol. $(\text{ft})^3 (\text{lbm})^{-2}$	Vap.Enth. (btu) $(\text{lbm})^{-4}$	Liq.Enth. (Btu) $(\text{lbm})^{-4}$	Liq.Enth. (Btu) $(\text{lbm})^{-4}$	Liq.Enth. (Btu) $(\text{lbm})^{-1}$ $(^{\circ}\text{R})^{-4}$	Liq.Enth. (Btu) $(\text{lbm})^{-4}$ $(^{\circ}\text{R})^{-1}$
10	26.617	0.01202	1.736	15.187	104.471	0.03408	0.22418
70	85.787	0.01312	0.558	34.583	112.652	0.07264	0.22003

- (a) What is the value of the coefficient of performance for a Carnot refrigerator ?.
 (b) Calculate the coefficient of performance for the vapor compression refrigeration cycle provided with an expander.
 (c) Calculate the coefficient of performance for the vapor compression refrigeration cycle provided with a throttle valve and a compressor efficiency of 0.8. [16]
8. A Carnot engine is coupled to a Carnot refrigerator so that all the work produced by the engine is used by the refrigerator in extraction of heat from a heat reservoir at 0°C at the rate of 35 kJ s^{-1} . The source of energy for the Carnot engine is a heat reservoir at 250°C . If both the devices discard heat to the surroundings at 25°C , how much heat does the engine absorb from its heat source reservoir? [16]

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1. (a) Define 'Thermodynamic property' giving examples. How they are classified?
 (b) What is the difference between primary and derived properties with suitable examples. [8+8]

2. State and explain the four laws of Thermodynamics. Why it became necessary to propose second law. [16]

3. (a) What is enthalpy? Is enthalpy a path function?
 (b) One kilogram mass of water is vaporized at 25°C and 1 atmospheric pressure, calculate ΔU and ΔH if 10.2374×10^4 joules heat is added to water.
 Data: Specific volume at 1 atm 25°C.

$$\text{Liquid water} = 1.044 \times 10^{-3} \text{ m}^3/\text{kg}.$$

$$\text{Water vapour} = 1.68 \text{ m}^3/\text{kg}.$$
 (c) State the 'first law of thermodynamics' [4+8+4]

4. A system containing 0.2 m^3 of air at a pressure of 4 bar and 160°C expands isentropically to a pressure of 1.06 bar and after this the gas is heated at constant pressure till the enthalpy increases by 65 kJ. Calculate the work done. Now imagine that these processes are replaced by a single reversible polytrophic process producing the same amount work between the initial and final state, find the index of expansion in this case. Take C_p of air as 1.005 kJ / kg K. [16]

5. Define the following:
 - (a) State
 - (b) Process
 - (c) Property
 - (d) Cycle [4x4]

6. A reversible heat engine, employing an ideal gas with constant specific heats, follows the following cycle: constant-volume heating from state 1 to state 2, adiabatic expansion from state 2 to state 3, and a constant-pressure process from state 3 to state 1. Show that for this cycle the ratio of net work produced to heat absorbed is given by

$$\frac{W}{Q} = (1 - \gamma) \frac{V_3/V_1 - 1}{P_2/P_1 - 1}$$
[16]

7. (a) Explain Carnot refrigerator and derive the relation for COP?

- (b) A Carnot refrigerator is operating between two reservoirs at temperatures $-25^{\circ}C$ and $35^{\circ}C$. Determine COP of the refrigerator. [10+6]
8. Discuss briefly how liquefaction can be achieved. Write energy balance equation around the separator, valve or cooler for Linde liquefaction process. [16]
