BITS-PILANI, DUBAI CAMPUS

Dubai International Academic City, Dubai, U.A.E.

II and III Year Chemical Engineering, I Semester 2012-'13

Comprehensive Exam

CHE F213/CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 80 Weightage: 40%

Duration: 3 hr **(Closed Book)** 31.12.2012

Note: This question paper contains 2 pages.
Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

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1. (a) A hydro turbine-generator operates with ahead of water at 50 m. The inlet and outlet conduits are 2 m diameter. Determine the mechanical power developed by the turbine for an outlet velocity of 10 ms^{-1}. (3 M)

   (b) One kg of air is heated reversibly at constant pressure from an initial state of 500 K and 1 bar until its volume doubles. Calculate the *W, Q,* ΔU and ΔH for the process. Assume air as ideal gas with $(PV/T) = 83.14\ bar\ cm^3\ mol^{-1}\ K^{-1}$ and $Cp = 29\ J\ mol^{-1}\ K^{-1}$. (5 M)

   (c) One mole of an ideal gas with $C_p = (7/2)\ R$ & $C_v = (5/2)\ R$ is expanded from 8 bar to 1 bar pressure at *600 K* by each of the following paths: (i) Constant temperature (ii) Adiabatically (iii) Constant volume. Assuming mechanical reversibility, calculate *W, Q,* ΔU and ΔH for each process. (8 M)

2. (a) Discuss chemical potential and phase equilibria (3 M)

   (b) Calculate the standard heat at 25 °C for the following reaction.

   $$2\ HCl_{(g)} + \tfrac{1}{2}\ O_{2\ (g)} \longrightarrow 2\ H_2O_{(g)} + 2\ Cl_{2\ (g)}$$ (5 M)

   (c) Determine the final temperature, pressure and work done, when one m^3 of an ideal gas at 600 K and 1 MPa expands to five times of its initial volume through a (i) mechanically reversible isothermal process (ii) mechanically reversible adiabatic process.($C_p = 21\ J\ mol^{-1}\ K^{-1}$) (8 M)

3. (a) Determine the power developed and heat rejected by a Carnot's engine which receives 300 kJ s^{-1} of heat at 500 °C and rejects heat to a sink at the ambient temperature. (3 M)

(b) In a constant volume process, an ideal gas with $Cv=5/2\ R$, at 700 K and 1.55 *bar* pressure receives 20 kJ of heat. Determine its entropy change if the gas is confined in volume of 1000 dm^3. Determine the entropy change if the above process is adiabatic. Comment on the irreversibility of the process. (5 M)

(c) Liquid water at 40 °C is mixed with superheated steam at 700 kPa and 280 °C (mass flow rate is 50 kg s^{-1}) to produce steam at 700 kPa and 200 °C. Assuming adiabatic operation determine the mass flow rate of liquid water to the mixer. Calculate the entropy generation rate and comment on the irreversible feature of the process. (8 M)

4. (a) Air discharges from an adiabatic nozzle at 25 °C with a velocity of 700 m s^{-1}. Determine the temperature at the entrance of the nozzle if the entrance velocity is 1 m s^{-1}. (Air-ideal gas with $Cv=5/2\ R$ *and* $Cp=7/2\ R$) (3 M)

(b) Steam at a rate of 1 kg s^{-1} undergoes an isentropic expansion in a nozzle from 1 MPa, 500 °C to 500 kPa. If the inlet velocity is negligible, calculate the exit velocity and the area of cross section of the nozzle exit. (5 M)

(c) A Carnot engine is coupled to a Carnot refrigerator so that all of the work produced by the engine is used by the refrigerator in extraction of heat from a heat reservoir at 10 °C at the rate of 45 kW. The source of energy for the Carnot engine is a heat reservoir at 250 °C. If both devices discard heat 25 °C to the surroundings at, how much heat does the engine absorb from its heat source reservoir? If the actual coefficient of performance of the refrigerator is $\omega = 0.63\ \omega_{carnot}$ and if the thermal efficiency of the engine is $\eta = 0.63\ \eta_{carnot}$, how much heat does the engine absorb from its heat source reservoir? (8 M)

5. (a) Write a note on H_2 fuel cell. (3 M)

(b) Determine the heat effect in the absorption of 2 mol of HCl(g) by a solution containing 1 mol of HCl and 4.5 mol of water at a temperature of 25 °C. (5M)

(c) Determine the BUBL point pressure for methane(1)/ethane(2)/propane(3) system at -40 ^oF [Given $x_1 = 0.20$ and $x_2 = 0.30$]. Also calculate the DEW point pressure for the same system at -40 ^oF [Given $y_1 = 0.60$ and $y_2 = 0.30$] (8M)

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DUBAI

FIRST SEMESTER, 2012-2013

TEST- 2 (Open Book)

Course Title: Chem. Engg. Thermodynamics **Course No: CHE F213/ CHE C311**

Date: 18.11.2012 **Max Marks: 20**

Time: 50 min **Weightage:20%**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct. Only Hand Written notes and prescribed Test/Reference books are permitted.

1. Steam at 1600 kPa and 500 °C at a rate of 25 kg s^{-1} is fed in to a turbine which operates adiabatically. The exit stream is 50 kPa at 100 °C. Determine the turbine efficiency in comparison with a turbine operating reversibly and adiabatically from the same initial condition to the same final pressure. Calculate the superheat (5 M)

2. Superheated steam at 4000 kPa and 400 °C is used to heat a stream of liquid water at 80 °C. The exit is saturated vapor with a flow rate of 20 kg s^{-1} at 2500 kPa. What is the mass flow rate of liquid water and $S_G$dot? Assuming the process to be adiabatic comment on the reversibility of the process. (7 M)

3. An engine operates between the temperatures 588 and 293 K and generates 750 MW power. How much heat is discarded at the sink and what would be the efficiency of the engine? If the actual efficiency is 35 % of the Carnot's efficiency, at what rate heat must be discarded to the sink? (4 M)

4. A light fuel oil with an average chemical composition $C_{10}H_{18}$ in burned with oxygen in a bomb calorimeter. The heat evolved in the reaction is 43,960 J g^{-1} at 298 K. Calculate the standard heat of combustion of the fuel oil at 298 K. Assume liquid water and gaseous CO_2 as products. (4 M)

BITS PILANI, DUBAI CAMPUS, INTERNATIONAL ACADEMIC CITY

DUBAI

FIRST SEMESTER, 2012-2013

TEST- 1 (Closed Book)

Course Title: Chem. Engg. Thermodynamics **Course No: CHE F213/ CHE C311**

Date: 30.09.2012 **Max Marks: 25**

Time: 50 min **Weightage:25%**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. A hydro-turbine is operating with water at a mass flow rate of 1 kg/s from a height of 50 m. Assume there is 80 % efficiency in conversion of potential energy in to electrical. Calculate the final power out put if there is 12 % loss in transmission of electrical energy. (4M)

2. A frictionless piston cylinder assembly (diameter 0.7 m) is confined with a gas in it. A dead weight of 100 kg rests on the piston (50 kg). The local acceleration due to gravity is $9.81 ms^{-2}$ and the atmospheric pressure is 101 kPa. Calculate the pressure of the gas and the total force experienced by the gas from the atmosphere, piston and weight. If the gas in the cylinder is heated to expand, it pushes the piston and weight upward by 0.8 m. Calculate the work done and the change in potential energy of the piston and weight. (6M)

3. A perfectly insulated steel tank of mass 25 kg contains 50 kg of water at 298 K. A steel casting of 100 kg at 1273 K is immersed in the water and allowed to reach equilibrium. Calculate the final temperature, if the specific heats of water and steel are 4.18 kJ kg^{-1} K^{-1} and 0.5 kJ kg^{-1} K^{-1} respectively. (5M)

4. Steam flows at steady 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 K and 700 kPa, and the velocity is 30 ms^{-1}. At the nozzle exit (state 2), the steam temperature and pressure are 513 K and 350 kPa respectively. The property values are: H_1 = 3112.5 kJ; H_2 = 2945.7 kJ; V_1= 388.61 cm^3g^{-1}; V2 = 667.75 cm^3g^{-1}. Calculate the exit velocity and the diameter of the nozzle at the exit. (5M)

5. (a) A rigid vessel containing 0.5 kmol of nitrogen at 25 °C is heated to 400 °C. How much heat is required if the vessel has negligible heat capacity? If the vessel weighs 100 kg and has a heat capacity of 0.5 kJ kg^{-1} K^{-1}, how much heat is required?

   (b) A frictionless piston cylinder assembly contains 5 kmol of nitrogen at 500 K. If it is cooled at constant pressure to 298 K, how much heat is released. Neglect the heat capacity of the piston cylinder assembly. [Cv = (5/2)R and Cp = (7/2)R for nitrogen gas]. (5M)

BITS PILANI – DUBAI CAMPUS

FIRST SEMESTER : 2012 – 2013

QUIZ-2 (Closed Book)

Course Code: CHE F213 / CHE C311		Date	: 10-12-2012
Course Title	: Chemical Engineering Thermodynamics	Max Marks	: 7
Duration	: 20 minutes	Weightage	: 7 %

Name: ..... **ID No:** ..... **Sec / Prog:** .....

Instructions: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. Water exits from an adiabatic pump at 8600 kPa. Calculate the final temperature if its entry is at 45 °C, 10 kPa. Given that the shaft work of the pump is 11.6 kJ kg^{-1}, V = 1010 cm^3 kg^{-1}, $\beta = 425 \times 10^{-6}$ K^{-1} and $C_p = 4.18$ kJ kg^{-1} K^{-1}. (3 M)

2. Relate the efficiency of a turbine with $Ws_{(isentropic)}$ and $(\Delta H)s$. (1 M)

3. Calculate the quality, if saturated water at 1000 kPa is throttled to a pressure of 101.325 kPa. Assume $H_2 = 762.6$ kJ kg^{-1}, $H^l = 419$ kJ kg^{-1}, $H^v = 2676$ kJ kg^{-1} and $\Delta H = 0$. (2M)

4. What will be the range of efficiency of a compressor and write the formula to calculate it. (1M)

BITS PILANI – DUBAI CAMPUS

FIRST SEMESTER : 2012 – 2013

QUIZ-1 (Closed Book)

Course Code: CHE F213 / CHE C311		Date	: 23-10-2012
Course Title	: Chemical Engineering Thermodynamics	Max Marks	: 8
Duration	: 20 minutes	Weightage	: 8 %

Name: ..... **ID No:** ..... **Sec / Prog:** .....

Instructions: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. Calculate $(\delta P/\delta T)_v$ of a pure liquid at 20 °C and 1 bar, if its volume expansivity is 7.5×10^{-3} $°C^{-1}$ and isothermal compression is 3×10^{-4} bar^{-1}. (2M)

2. Calculate the work done and initial pressure when one mole of an ideal gas undergoes an adiabatic compression to 5 bar, from 50 °C to 150 °C with Cv = (5/2)R and Cp= (7/2)R (2M)

3. Calculate the molar volume of saturated liquid formaldehyde at 80 °C, if its Vc = 115 cm^3/mol, Tc = 408 K and Zc = 0.223. (2M)

[P.T.O.]

4. Draw a representative PV diagram of a pure substance indicating the Liq/Liq-Vap/Vap regions with isotherms. (2M)

BITS PILANI – DUBAI CAMPUS

FIRST SEMESTER : 2012 – 2013

QUIZ-1 (Closed Book)

Course Code: CHE F213 / CHE C311 | Date : 23-10-2012

Course Title : Chemical Engineering Thermodynamics | Max Marks : 8

Duration : 20 minutes | Weightage : 8 %

Name: ..... **ID No:** ..... **Sec / Prog:** .....

Instructions: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. Calculate $(\delta P/\delta T)_v$ of a pure liquid at 20 °C and 1 bar, if its volume expansivity is 7.5×10^{-3} $^{\circ}C^{-1}$ and isothermal compression is 3×10^{-4} bar^{-1}. (2M)

2. Calculate the work done and initial pressure when one mole of an ideal gas undergoes an adiabatic compression to 5 bar, from 50 °C to 150 °C with Cv = (5/2)R and Cp= (7/2)R. (2M)

3. Calculate the molar volume of saturated liquid formaldehyde at 80 °C, if its Vc = 115 cm^3/mol, Tc = 408 K and Zc = 0.223. (2M)

4. Draw a representative PV diagram of a pure substance indicating the Liq/Liq-Vap/Vap regions with isotherms. (2M)