



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS

TCE 6102

Final Examination Paper

January 2025

This examination paper consists of 5 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Chemical Engineering Thermodynamics Tables

Examiner's Name : N. G. Mguni

External Examiner: Dr A. Mamvura

INSTRUCTIONS

1. Answer ANY FOUR (4) QUESTIONS
2. Each question carries 25 marks
3. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
1.	25
2.	25
3.	25
4.	25
5.	25
6.	25
TOTAL ATTAINABLE MARKS	100

Page 1 of 5

Answer ANY FOUR (4) questions

QUESTION 1

a. In a single-heater regenerative cycle, steam enters the turbine at 30 bar, 400°C, and the exhaust pressure is 0.1 bar. The feedwater, the efficient, and the eater is a direct contact type, which operates at 5 bars. Find

(i) The efficiency and the steam rate of the cycle. [12]

(ii) What is meant by power generation? [2]

(iii) What is the basic principle of power generation? [2]

b. Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 30 kJ of heat is transferred to the water, and 5 kJ of heat is lost to the surrounding air. The paddle-wheel work amounts to 500 N · m. Determine the final energy of the system if its initial energy is 10 kJ. [5]

c. 10-kg of R-134a fill a 1.348-m³ rigid container at an initial temperature of 240°C. The container is then heated until the pressure is 200 kPa. Determine the final temperature and the initial pressure.

[6]

QUESTION 2

a. State the First Law of Thermodynamics. [2]

b. State the Second Law of Thermodynamics and state the statement according to the authors.

[6]

c. What is a heat engine and give an example. [2]

d. A piston-cylinder device contains 0.85 kg of refrigerant-134a at -10°C. The piston that is free to move has a mass of 12 kg and a diameter of 25 cm. The local atmospheric pressure is 88 kPa. Now, heat is transferred to refrigerant-134a until the temperature is 15°C. Determine

(i) the final pressure [3]

(ii) the change in the volume of the cylinder [4]

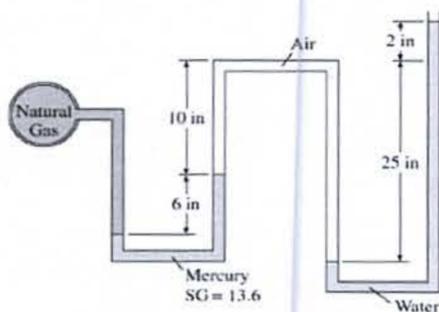
(iii) the change in the enthalpy of the refrigerant-134a. [3]

e. What is the difference between a refrigerator and an air conditioner? [2]

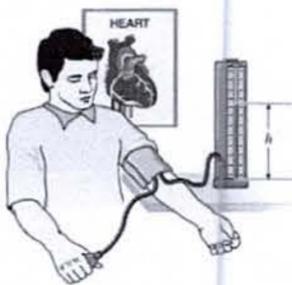
f. Determine the COP of a refrigerator that removes heat from the food compartment at a rate of 5040 kJ/h for each kW of power it consumes. Also, determine the rate of heat rejection to the outside air. [3]

QUESTION 3

- a. What is meant by standard Gibbs free energy change of a chemical reaction? [5]
- b. One kmol of octane (C_8H_{18}) is burned with air that contains 20 kmol of O_2 . Assuming the products contain only CO_2 , H_2O , O_2 , and N_2 , determine the mole number of each gas in the products and the air-fuel ratio for this combustion process. [8]
- c. What is more efficient diesel or petrol engines? Explain [3]
- d. The pressure in a natural gas pipeline is measured by the manometer shown in Fig. with one of the arms open to the atmosphere where the local atmospheric pressure is 14.2 psia. Determine the absolute pressure in the pipeline. [6]



- e. The maximum blood pressure in the upper arm of a healthy person is about 120 mmHg. If a vertical tube open to the atmosphere is connected to the vein in the arm of the person, determine how high the blood will rise in the tube. Take the density of the blood to be 1050 kg/m^3 . [3]



QUESTION 4

- a. Propane and methane are commonly used for heating in winter, and the leakage of these fuels, even for short periods, poses a fire danger for homes. Which gas leakage do you think poses a greater risk for fire? Explain. [3]
- b. Methane at 10 MPa and 300 K is heated at constant pressure until its volume has increased by 80 percent. Determine the final temperature using the ideal gas equation of state and the compressibility factor. Which of these two results is more accurate? [10]
- b. For steady flow through a heat exchanger at approximately atmospheric pressure, what is the final temperature,

i. When heat in the amount of 800 kJ is added to 10 mol of ethylene initially at 473.15 K? [6]

ii. When heat in the amount of 2500 kJ is added to 15 mol of 1-butene initially at 533.15 K? [6]

$$Q = n.R \left[\left[A.T_0(\tau - 1) + \frac{B}{2} T_0^2(\tau^2 - 1) \right] + \frac{C}{3} \cdot T_0^3 \cdot (\tau^3 - 1) \right]$$

QUESTION 5

a. Differentiate between residual and excess properties. [4]

b. In a laboratory, there is a need for 2 000 cm³ of an antifreeze solution consisting of 30 mol% methanol in water. What volumes of pure methanol and pure water at 25°C must be mixed to form the 2 000 cm³ of antifreeze also at 25°C. Partial molar volumes for methanol and water in a 30 mol% methanol solution and their pure-species molar volumes both at 25°C are: [5]

$$\text{Methanol(1): } \bar{V}_1 = 38.632 \text{ cm}^3\text{mol}^{-1} \quad V_1 = 40.727 \text{ cm}^3\text{mol}^{-1}$$

$$\text{Water (2) : } \bar{V}_2 = 17.765 \text{ cm}^3\text{mol}^{-1} \quad V_1 = 18.068 \text{ cm}^3\text{mol}^{-1}$$

c. SO₂ is emitted from a local plant at 600 K and 300 bar, determine good estimates of fugacity and G^R/RT. [5]

d. Calculate the volume occupied by one mole of n-octane vapour at 427.85 K where the saturation vapour is 0.215 MPa. Assume that n-octane follows van der Waals equation of state. The van der Waals constants a and b are 3.789 Pa (m³/mol)² and 2.37 x 10⁻⁴ m³/mol respectively. [6]

$$v = \frac{RT}{\left(P + \frac{a}{v}\right)} + b$$

e. Determine the standard heat of the following reactions at 25°C.



QUESTION 6

a. State Raoult's law. [2]

b. What is a dew point and bubble point? [4]

c. A single-stage liquid/vapour separation for the benzene (1)/ethylbenzene (2) system must produce phases of the following equilibrium compositions. Determine the T and P in the separator for one of these sets. What additional information is needed to compute the relative amounts of liquid and vapour leaving the separator? Assume that Raoult's law applies [10]

(i) $x_1 = 0.35$, $y_1 = 0.70$.

(ii) $x_1 = 0.35$, $y_1 = 0.725$.

d. A mixture comprised of 30-mol-% methane, 10-mol-% ethane, 30-mol-% propane, and 30-mol-% n-butane is brought to a condition of 258.15 K (-15°C) at pressure P, where it exists as a vapour-liquid mixture in equilibrium. If the mole fraction of the methane in the vapour phase is 0.80, what is pressure P (in bar)? [9]

(END OF EXAMINATION PAPER)