Final Assessment Test (FAT) – November/December 2022

Programme	B.Tech.	Semester	Fall Semester 2022-23
Course Title	ENGINEERING THERMODYNAMICS	Course Code	BMEE203L
Faculty Name	Prof. Feroskhan M	Slot	A1+TA1
		Class Nbr	CH2022231001747
Time	3 Hours	Max. Marks	100

Make suitable assumptions wherever necessary and justify the same
Usage of Steam Property Tables & Compressibility Charts Permitted

Part 1 (10 X 10 Marks)
Answer any 10 questions

1. Briefly explain the following processes with the help of sketches and examples wherever necessary: (i) Isothermal process, (ii) Isochoric process, (iii) Isobaric process, (iv) Adiabatic process and (v) Isentropic process. [10]

2. Steam is available at 175 bar and 600°C . Determine its specific volume using (i) Ideal gas equation, (ii) Van der Waals equation, (iii) Compressibility chart, and (d) Steam tables. Which one is the most accurate among the four? Accordingly, compute the percentage error involved in the remaining three results. [10]
Van der Waals equation is given as:
$$\left(P+\frac{a}{v^2}\right)(v-b)=RT$$
$$a=\frac{27R^2T_c^2}{64P_c} \quad \text{and} \quad b=\frac{RT_c}{8P_c}$$

3. A two-phase liquid–vapor mixture of H_2O with an initial quality of 25% is contained in a piston–cylinder assembly as shown in the figure 1 below. The mass of the piston is 40 kg, and its diameter is 10 cm. The atmospheric pressure of the surroundings is 1 bar. The initial and final positions of the piston are shown in the figure. As the water is heated, the pressure inside the cylinder remains constant until the piston hits the stops. Heat transfer to the water continues until its pressure is 3 bar. Assume friction between the piston and the cylinder wall is negligible. Determine the total amount of heat transfer, in J. [10]

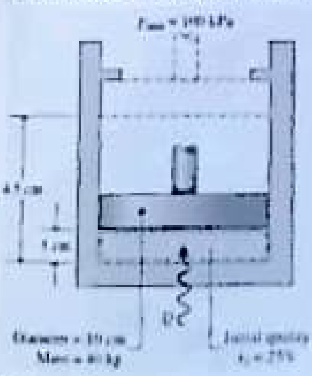

Figure 1

4. Air is contained in a vertical piston–cylinder assembly by a piston of mass 50 kg and having a face area of 0.01 m^2. The mass of the air is 5 g, and initially the air occupies a volume of 5 litres. The atmosphere exerts a pressure of 100 kPa on the top of the piston. The volume of the air [10]

slowly decreases to 0.002 m^3 as the specific internal energy of the air decreases by 260 kJ/kg. Neglecting friction between the piston and the cylinder wall, determine the heat transfer to the air, in kJ.

5. A large, steady expansion engine has two low velocity flows of water entering. High-pressure steam enters at point 1 with 2.0 kg/s at 2 MPa, 500°C, and 0.5 kg/s of cooling water at 120 kPa, 30°C enters at point 2. A single flow exits at point 3, with 150 kPa and 80% quality, through a 0.15 m diameter exhaust pipe. There is a heat loss of 300 kW. Draw the schematic diagram and find the exhaust velocity and the power output of the engine.

6. Give the two statements of the 2nd Law of Thermodynamics and prove their equivalence.

7. Compressed air enters a counterflow heat exchanger operating at steady state at 610 K, 10 bar and exits at 860 K, 9.7 bar. Hot combustion gas enters as a separate stream at 1020 K, 1.1 bar and exits at 1 bar. Each stream has a mass flow rate of 90 kg/s. Heat transfer between the outer surface of the heat exchanger and the surroundings can be ignored. Assuming the combustion gas stream has the properties of air, and using the ideal gas model for both streams, determine for the heat exchanger:

(a) the exit temperature of the combustion gas, in K.

(b) the net change in the flow exergy rate from inlet to exit of each stream, in MW.

(c) the rate exergy destroyed, in MW.

Let $T_0 = 300$ K, $p_0 = 1$ bar.

8. A four stroke SI engine has the compression ratio of 6 and swept volume of 0.15 m^3. Pressure and temperature at the beginning of compression are 98 kPa and 60°C respectively. Determine the pressure, volume and temperature at all salient points if heat supplied is 150 kJ/kg. Also find out entropy change, work done, efficiency and mean effective pressure of cycle assuming $C_p = 1$ kJ/kg·K, $C_v = 0.71$ kJ/kg·K. Also plot the cycle on T-S diagram.

9. A large stationary gas turbine power plant delivers a power output of 100 MW to an electric generator. The minimum temperature in the cycle is 300 K, and the exhaust temperature is 750 K. The minimum pressure in the cycle is 100 kPa, and the compressor pressure ratio is 14:1. Calculate the power output of the turbine. What fraction of the turbine output is required to drive the compressor? What is the thermal efficiency of the cycle? [1

10. Consider a steam power plant that operates on the ideal reheat Rankine cycle. The plant maintains the boiler at 4000 kPa, the reheat section at 500 kPa, and the condenser at 10 kPa. The mixture quality at the exit of both turbines is 90%. Determine the temperature at the inlet of each turbine and the cycle's thermal efficiency. [10

11. An insulated rigid tank is divided into two compartments by a partition. One compartment contains 7 kg of O_2 at 40 °C and 100 kPa, and the other compartment contains 4 kg of N_2 at 20 °C and 150 kPa. Now the partition is removed, and the two gases are allowed to mix. Determine (a) the mixture temperature and (b) the mixture pressure after equilibrium has been established. Take $C_{v,N_2} = 0.743$ kJ/kg-K and $C_{v,O_2} = 0.658$ kJ/kg-K. [10]

12. Starting with the Maxwell relation given below, derive the Clapeyron equation and the Clausius-Clapeyron equation. [10]

$$\left(\frac{\partial P}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$$