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Ref. No. Ex/PG/PE/T/111A/31/2017

M. POWER ENGINEERING FIRST SEMESTER EXAMINATION 2017

SUBJECT: ***APPLIED THERMODYNAMICS I***

Time: Three Hours **Full Marks 100**

Answer Question No. 1 and any **three** from the rest

1. **Answer any 5** **5×8 = 40**

a. Show that an isobar in the Mollier diagram is a straight line in the wet region and a rising curve in the superheated region. If the υ= constant lines in Mollier chart are steeper than the p= constant lines, is $\left(\partial T/\partial \upsilon\right)_{s=constant}$ positive or negative? **4+4 = 8**

b. Write the van der Waals equation of state of a gas and derive an expression for the entropy change for such a gas. **8**

c. A room contains 20 m^3 of humid air at 30 °C DBT and 50% relative humidity at 1.013 bar. Water/steam at 1.013 bar pressure is sprayed in the room so that the WBT rises to 30 °C, but the DBT remains the same. What is the mass of steam/water sprayed in the room, and what temperature was it sprayed at? **8**

d. A Carnot heat engine receives energy from a reservoir at T_{res} through a heat exchanger (see Fig 1) where the heat transfer is proportional to the temperature difference, i.e., $\dot{Q} = K\left(T_{res} - T_H\right)$, where K is a proportionality constant. It rejects heat at a given low temperature T_L. To design the heat engine for a maximum work output, show that the high temperature, T_H, in the cycle should be selected as $T_H = \sqrt{T_L T_{res}}$. Also find out the expression for the maximum power. **8**

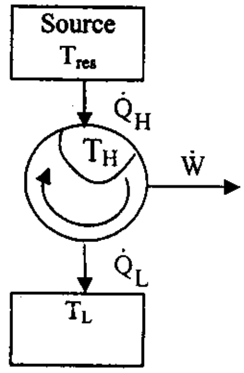

Fig 1

e. A rigid, insulated vessel contains two equal chambers of 1 m^3 volume (each) containing two ideal gases A (molecular wt 50, γ = 1.5) and B (molecular wt 25, γ = 1.6), respectively. Both the chambers are initially at 5 bar and 400 K. The two chambers are now connected by removing the intervening partition. Estimate the final pressure, temperature and the entropy generated in the mixing process. **8**

f. Steam enters an adiabatic turbine at 80 bar and 500°C and it exhausts at 10 bar. If the isentropic efficiency of the turbine is 90%, find the second law efficiency of the turbine. **8**

2.

a. State Kelvin Planck and Clausius statements and show that they are equivalent. 2+3

b. A 100 MW power plant receives 200 MW heat from a 1200 K reservoir; but as the heat reaches the engine through a heat exchanger the temperature drops to 900 K. The cycle rejects heat to 300 K atmosphere (see Fig 2). Estimate the entropy generation (i) within the heat exchanger, (ii) within the heat engine. 15

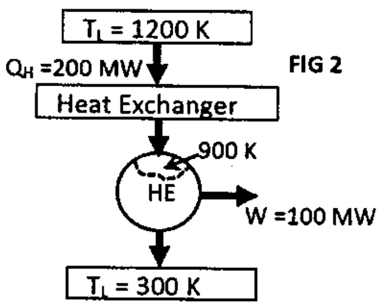

FIG 2

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SUBJECT: ***APPLIED THERMODYNAMICS I***

Time: Three Hours **Full Marks 100**

3. Figure 3 provides steady-state operating data for a well-insulated device with air entering at one location and exiting at another with a mass flow rate of 10 kg/s. Assuming ideal gas behavior and negligible potential energy effects, determine the direction of flow (i.e., L to R or R to L). Is it a power producing or power consuming device? Find out the power, in kW. Use the Air property table at the end of the question paper. 20

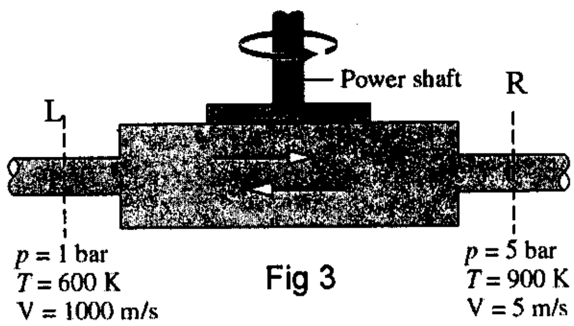

Fig 3

4.

a. Write down the expression of Availability transport equation for a flow system and explain the significance of each term. 5

b. Air enters a compressor at an ambient condition of 100 kPa and 27 °C with a low velocity and exits at 1 Mpa, 327 °C and a velocity of 105 m/s. The compressor is cooled by an ambient air at 27 °C at a rate of 25 kW. The power input to the compressor is 300 kW. Determine (a) the mass flow rate of air through the compressor, (b) portion of the input power that is spent just to overcome the irreversibilities. Use the air chart provided at the end of the question paper. 15

5. A gas mixture consists of 2 kg of N_2 and 3 kg of He. Determine (a) the composition in terms of mole fractions, and (b) the heat transfer, in kJ, required to increase the mixture temperature from 27°C to 127°C, while keeping the pressure constant. (c) Also find the change in entropy of the mixture for the process. Use the ideal gas model with constant specific heats. 20

6. Air enters a natural draft cooling tower at 1.013 bar and 13 °C and a relative humidity of 50%. Water at 60 °C from the turbine condenser is sprayed into the tower at a rate of 22.5 kg/s and leaves at 27 °C. The air leaves from the top of the tower at 38 °C, 1.013 bar and saturated. Determine the air-flow rate and the make-up water requirement per second. 20

7.

a. Write down the Maxwell equations and describe its utility. 5

b. Show that Joule Thomson coefficient for a pure substance can be written as

$$\mu_J = \frac{T^2}{C_p}\left(\frac{\partial(\upsilon/T)}{\partial T}\right)_p$$ 15

Air Table (source: Thermodynamics by Cengel and Boles, 8th Ed)

T (K)	*u (kJ/kg)*	*h (kJ/kg)*	*s^0 (kJ/kgK)*	*T (K)*	*u (kJ/kg)*	*h (kJ/kg)*	*s^0 (kJ/kgK)*
200	142.56	199.97	1.29559	600	434.78	607.02	2.40902
300	214.07	300.19	1.70203	700	512.33	713.27	2.57277
400	286.16	400.98	1.99194	800	592.3	821.95	2.71787
500	359.49	503.02	2.21952	900	674.58	932.93	2.84856