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Ref. No. Ex/PE/T/211/2017(S)

B POWER ENGINEERING EXAMINATION, 2^{nd} YEAR First Sem Supple 2017

SUBJECT: ***ENGINEERING THERMODYNAMICS I***

Time: Three Hours

(Full Marks 100)

Answer question number 1, and any *FOUR* from the rest

1.

a. State the two corollaries of second law of thermodynamics and show that they are equivalent **6**

b. A heat engine receives $1/3^{rd}$ of its input heat at a temperature of 1000 K, $1/3^{rd}$ at 750 K and the rest at 500 K, while rejecting heat at 300 K. What is the maximum possible thermal efficiency of the heat engine? **8**

c. **State if the following Statements are true (T) or false (F)** **6×1= 6**

- i) PMM II obeys the First Law of Thermodynamics
- ii) No mass transfer can take place across the boundary of a control volume
- iii) Specific heat of an ideal gas cannot be negative
- iv) Entropy of a closed system remains constant during isothermal expansion process
- v) Heat transfer with finite temperature difference is an example of external irreversibility
- vi) COP of a reversible heat pump and refrigerator operating between the same two temperature differences are identical.

2.

a. An electric motor operating at steady state draws a current of 10 A with a voltage of 220 V. The output shaft rotates at 900 rpm with a torque 16 N.m applied to an external load. The rate of heat transfer from the motor to its surroundings is related to the surface temperature T_b and the ambient temperature T_0 by the relationship $\dot{Q} = hA(T_b - T_0)$, where h = 100 W/m^{2}K, A = 0.2 m^2, and T_0 = 293 K. Energy transfers are indicted by the arrows shown in the Fig. P2a.

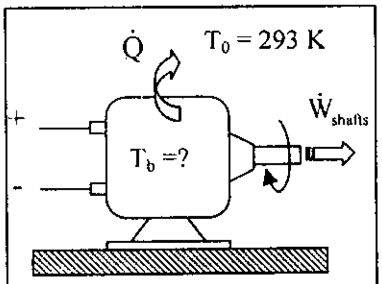

Fig P2a

i) Determine the temperature T_b in K

ii) For just the motor as the system (i.e., its surface as the system boundary), calculate the rate of entropy generation within the system, and the rate of entropy transfer with heat.

iii) Also, find out the total entropy generated in the universe **20**

b. Show that the entropy of a pure substance is a point function. **5**

3.

a. 1.5 kg of air can be expanded between two states as it does 31 kJ of work and receives 16 kJ of heat. A second kind of expansion can be found between the same initial and final states, which require a heat input of only 10 kJ. What is the change of specific internal energy in the first expansion? Also, what is the work done during the second expansion? **8 marks**

b. A quantity of air occupying a volume of 1 m^3 at 4 bar and 150°C is allowed to expand isentropically to 1 bar. Its enthalpy is then raised by 70 kJ by heating at constant pressure. What is the total work done during this process? If the process is to be replaced by a reversible polytropic expansion which results in the same final state being reached, what index of expansion is required? Will the work done be greater or less than that in the original process? Neatly draw the processes in p-v plot. **12**

4.

a. State the first law of thermodynamics for a cyclic process. What do you mean by PMM-I? **5**

b. A 0.5 m^3 insulated, rigid container has two equal chambers A and B separated by a thin, insulating, rigid wall. Both chambers contains a gas of C_p = 1 kJ/kg K, and γ = 1.3. Chamber A is at 50 bar and 300K, while chamber B is at 10 bar and 600 K. The separating wall is now ruptured and the gas in the container comes to equilibrium. Calculate the (i) final temperature and pressure of the gas and (ii) the entropy generated in the process. **15**

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(Full Marks 100)

5.

a. Write down the energy equation for a transient process in an open system. **5**

b. Steam enters a turbine with a pressure of 100 bars, and a temperature of 500°C, and a velocity of 100 m/s. Wet steam at 0.1 bar and 95% quality exits the turbine with a velocity of 150 m/s. At steady state, the turbine loses 120 kJ of heat per kg of steam flowing through the turbine. Heat transfer between the turbine and its surrounding occurs at an average outer surface temperature of 360K. Determine (i) the work output from the turbine, and (ii) the rate at which the entropy is generated within the turbine per kg of steam flowing. Neglect the change in the potential energy between the inlet and exit. **15**

6.

a. During the isothermal heat rejection process of a Carnot cycle, the working fluid experiences an entropy change of -0.6 kJ/K. If the temperature of the energy sink is 30° C, determine (a) the amount of heat transfer to the sink, (b) the entropy change of the sink, and (c) the total entropy change of the process. **10**

b. Define thermomechanical availability for a non-flow system. **5**

c. 5 kW/sqm. of heat is transferred across an insulator slab from a furnace at 1000 K to the ambient at 300 K. What is the exergy destruction per unit area of the slab? Assume a reference temeperature of 298 K. **5**

7.

a. Dry saturated steam at 10 bar is passed through a throttle valve to expand to a pressure of 1 bar. Find the final steam temperature. Also calculated the entropy generated in the process. **8**

b. A 20 kg aluminum block initially at 200° C is brought in contact with a 20 kg block of iron at 100° C in an insulated enclosure. Determine the final equilibrium temperature and the total entropy change for the process. Assume that the specific heats for Al and Fe are 0.90 kJ/(kg.K) and 0.45 kJ/(kg.K), respectively. **12**

8.

a. A furnace can deliver heat Q_1 at T_{H1} and it is proposed to use this to drive a heat engine with a heat rejection at T_{atm} instead of direct room heating. The heat engine drives a heat pump that delivers Q_{H2} at T_{room} using atmosphere as the cold reservoir (see Fig. P8a). Find the ratio Q_{H2}/Q_{H1} as a function of the temperatures. Is this a better setup than direct room heating from the furnace? **10**

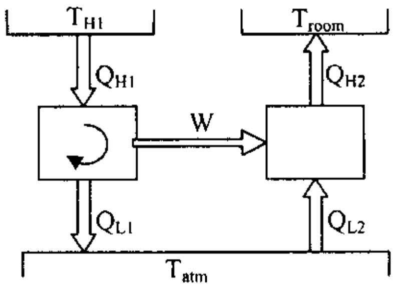

Fig. P8a

b. Water enters an ice machine at 15° C and leaves as ice at -5° C. If the COP of the ice machine is 2.4 durng this operation, determine the required power input for an ice production rate of 12 kg/h. (latent heat of melting is 335 kJ/kg, specific heat of water is 4.2 kJ/kg, and that of ice is 2.24 kJ/kg). 10