Ref. No. PE/PC/B/T/213/2024(S)

B. POWER ENGINEERING 2ND YEAR FIRST SEMESTER SUPPLE EXAMINATION 2024

SUBJECT: ***ENGINEERING THERMODYNAMICS***

Time: 24 Hours **Full Marks: 100**

Use of Air and Steam Table permitted; Other charts are supplied with the Question Paper

CO1: Answer any one questions 20 marks

1.

An insulated, rigid tank is divided into two compartments by a frictionless, thermally conducting piston. One compartment initially contains 1 m^3 of saturated water vapor at 4 MPa and the other compartment contains 1 m^3 of water vapor at 20 MPa, 800°C. The piston is released and equilibrium is attained, with the piston experiencing no change of state. For the water as the system, determine (a) the final pressure, in MPa, (b) the final temperature, in °C. (c) the amount of entropy produced, in kJ/K. **20**

OR

A proposed device (see Fig P1) to develop power using energy supplied to the device by heat transfer from a high-temperature industrial process together with a steam input. The figure provides data for steady-state operation. All surfaces are well insulated except for the one at 527°C, through which heat transfer occurs at a rate of 4.21 kW. Ignoring changes in kinetic and potential energy, evaluate the maximum theoretical power that can be developed, in kW. **20**

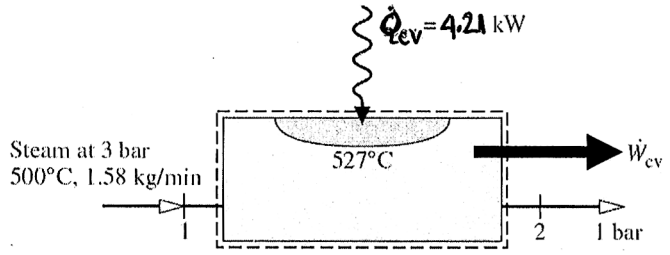

Fig. P1

CO2: Answer any two questions 40 marks

2.

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

b. 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 power developed and entropy generated per unit mass of steam flowing. **10**

c. 5 kW/m^2 of heat is transferred across an insulator slab from a furnace at 1000 K to the ambient at 300 K. What is the entropy generated and loss of work within the slab per unit area? **5**

3.

a. Prove from the corrolaries of the second law of thermodynamics that the COP of a reversible heat pump is always greater than that of an irreversible one. **5**

b. A proposed combined heat and power plant receives 800 MW of heat from two heat sources: 500 MW is received at 1000 K, and the remaining at 600 K. The plant supplies 200 MW of heat to maintain a process chamber temperature at 127 °C, and the rejects heat to the ambient at 300 K. The CHP produces 400 MW of power. Is the plant reversible, irreversible or a PMM-2? **15**

[Turn over

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4.

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/m²K, A = 0.2 m², and T_0 = 293 K. Energy transfers are indicted by the arrows shown in the Fig. P2a.

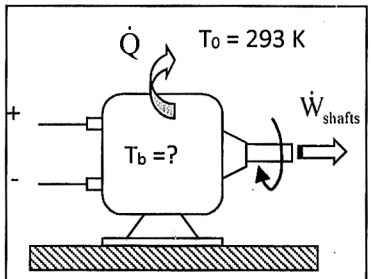

Fig P4

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**

CO 3: 25 marks

5.

a. What is the significance of (i) cycle heat rate, (ii) work ratio and (iii) specific steam consumption of a vapor power cycle? **5**

OR

What is the purpose of reheating in vapor power cycle? Draw a neat sketch of a reheat vapor power cycle on p-v, T-s and h-s diagrams. **5**

b. A steam power plant operates on an ideal reheat Rankine cycle between the pressure limits of 15 MPa and 10 kPa. The mass flow rate of steam through the cycle is 12 kg/s. Steam enters both HP and LP turbines at 500°C. If the moisture content of the steam at the exit of the low-pressure turbine is not to exceed 12 percent, determine (a) the pressure at which reheating takes place, (b) the total rate of heat input in the boiler, and (c) the thermal efficiency of the cycle. Also, show the cycle on a T-s diagram with respect to saturation lines. **20**

OR

Consider an ideal air standard Brayton cycle in which the air enters the compressor is at 100 kPa and 27°C, and the pressure ratio across the compressor is 12:1. The maximum operating temperature of the cycle is 1127°C, and the airflow rate is 10 kg/s. Determine the net work output, specific work, the work ratio, First-law and Second-law efficiency of the cycle. Plot the cycle on a p-v and T-s diagram.

20

CO 4: 15 marks

6.

What do you mean by 1 T of refrigeration? What is the purpose of the expansion valve in a vapor compression refrigeration system? **5**

OR

A humid room-air at 1 atmosphere pressure has a dew point of 25°C. Find out its relative humidity if a regular thermometer hung in the room reads 30 °C **5**

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7. A vapor compression refrigeration cycle with refrigerant R134a as the working fluid operates with an evaporator temperature of -20°C and a condenser temperature of 36°C. The mass flow rate of the refrigerant is 3 kg/min. Condition of the refrigerant at the compressor outlet is dry saturated. For the following properties of the R134a, find the Tonnage and COP of the refrigerator. Plot the cycle on a T-s and p-H diagram.

T (°C)	p (bar)	$\upsilon_f \times 10^3$ (m^3/kg)	υ_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kgK)	s_g (kJ/kgK)
-20	1.3299	0.7361	0.1464	24.26	235.31	0.00996	0.9332
36	9.1168	0.8590	0.0223	100.25	266.4	0.3678	0.9053

10

OR

A stream consisting of 35 m^3/min of moist air at 15°C, 1 atm, 80% relative humidity mixes adiabatically with a stream consisting of 50 m^3/min of moist air at 40°C, 1 atm, 40% relative humidity, giving a single mixed stream at 1 atm. Determine the relative humidity and temperature, in °C, of the exiting stream. Use the psychrometric chart provided at the end of the question paper. **10**

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