Ref. No. Ex/PE/PC/B/T/213/2024

B. POWER ENGINEERING 2ND YEAR FIRST SEMESTER EXAMINATION 2024

SUBJECT: **ENGINEERING THERMODYNAMICS**

Time: Three Hours **Full Marks: 100**

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

Part I (CO1): Answer any one questions 20 marks

1.

a. State the difference between a closed and open system. Give example of each. **3**

b. Why are the isotherms of a highly superheated steam in Mollier Chart nearly horizontal? **2**

c. A fluid system undergoes a non-flow frictionless process following the pressure-volume relation as $p = 5/V + 1.5$ where p is in bar and V is in m^3. During the process the volume changes from 0.15 m^3 to 0.05 m^3 and the system rejects 45 kJ of heat. Determine: (i) Change in internal energy; (ii) Change in enthalpy. **15**

OR

a. The properties of a 5 kg system, during a reversible constant pressure nonflow process at p = 1.6 bar, changed from $v_1 = 0.3$ m^3/kg, $T_1 = 20°C$ to $v_2 = 0.55$ m^3/kg, $T_2 = 260°C$. The specific heat of the fluid is given by $C_P = \left(1.5 + \frac{75}{T+45}\right)$ kJ/kgK. Determine (i) the heat added, (ii) work done, (iii) change in internal energy, (iv) change in enthalpy. **15**

b. Wet steam at 1 bar and $x=0.9$ is heated in a rigid vessel until it is dry saturated. Find the final pressure and the amount of heat added. **5**

Part II (CO 2): Answer any two questions 40 marks

2. N_2 Gas, Initially at 600 kPa and 600 K (state 1) undergoes an internally reversible cyclic process comprising of a constant volume process at 250 kPa (state 2), followed by an isothermal process to the initial pressure (state 3), and finally back to the initial volume through an isobaric process. Find (a) heat added to the cycle, (b) change of entropy during process 2-3, (c) net work done/consumed. Assume constant C_p and C_v for N_2. **20**

3.

a. State and prove Clausius inequality. **5**

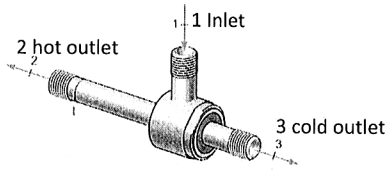
b. Determine the minimum theoretical power, in W, required at steady state by a refrigeration system to maintain a cryogenic sample at –126 °C in a laboratory room which is at 21 °C, if the energy leaks by heat transfer to the sample from its surroundings at a rate of 900 W. **10**

c. You have purchased a 2 T window-air conditioner that consumes ~1.75 kW of electric power. What is the COP of the air conditioner? In winter, you reverse-mount the AC to heat the room. How much heat do you supply, for the same consumption of electric power? **5**

4.

a. Cite the possible reasons of entropy generation during any thermodynamic process. **5**

b. A vortex tube has an air inlet flow at 20◦C, 200 kPa and two exit flows of 100 kPa: one at 0 °C and the other at 40 °C. The tube, shown in the figure has no external heat transfer and no work, and all the flows are steady and have negligible kinetic energy. Find the fraction of the inlet flow that comes out at 0◦C and the entropy generation rate. **15**



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Part III (CO 3): Answer any <u>one</u> question **25 marks**

5.

a. Discuss the purpose of using a supercritical vapor power cycle. **3**

b. Mention two benefits of a reheat cycle. **2**

c. A 210 MW (net) ideal regenerative cycle operates with a main steam parameters of 150 bar, 550°C and condenser back pressure of 0.1 bar. The single extraction from the turbine at 10 bar goes to a direct contact type heat exchanger. You may neglect the pump work. Draw a neat sketch and the *T-s* and *h-s* diagrams of the cycle. Evaluate (i) the heat rate, (ii) specific work output and (iii) steam flow rate. **20**

6.

a. A gasoline engine has a volumetric compression ratio of 10 and before compression has air at 290 K, 85 kPa, in the cylinder. The combustion peak pressure is 6000 kPa. Assume cold air properties. What is the highest temperature in the cycle? Find the temperature at the beginning of the exhaust (heat rejection) and the overall cycle efficiency **10**

b. A Brayton cycle has an operating temperature ratio of 5 and pressure ratio of 10. Evaluate the pressure at which the specific work output is maximum, and find out this maximum specific work output. **10**

c. Two simple cycles of efficiencies of 20% and 30% are coupled in such a way that the heat rejected by the more efficient topping cycle is fully received by the less efficient bottoming cycle. Find the combined cycle efficiency. **5**

[Consider for air C_p = 1.005 kJ/kgK, and γ=1.4]

Part IV (CO-4): **15 marks**

7.

a. What is the function of the capillary tube in a vapor compression refrigeration cycle? **3**

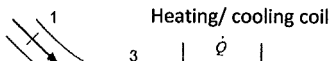
OR

Find the humidity ratio, dew point and partial pressure of water vapor in atmospheric air at 20°C and 80% relative humidity. **3**

b. A refrigerator in a laboratory uses R-134a as the working substance. The high pressure is 1200 kPa, the low pressure is 101.3 kPa, and the compressor is reversible. It should remove 500 W from a specimen at 20°C (not equal to T_L in the cycle) that is inside the refrigerated space. Find the cycle COP and the electrical power required. Also find the entropy generated in the evaporator. Use the enclosed property chart for R-134. **12**

OR

A flow of moist air at 21°C with 60% relative humidity should be produced from mixing two different moist air flows. Flow 1 is at 10 °C and 80% relative humidity; flow 2 is at 30 °C and has T_{wet} = 25 °C. The mixing chamber can be followed by a heater or a cooler as shown in the Figure. No liquid water is added, and P 100 kPa. Find the ratio of the two mass flow rates $\dot{m}_{a1}/\dot{m}_{a2}$ and the heat transfer in the heater/cooler per kilogram of dry air. Use the attached psychrometric chart. **12**



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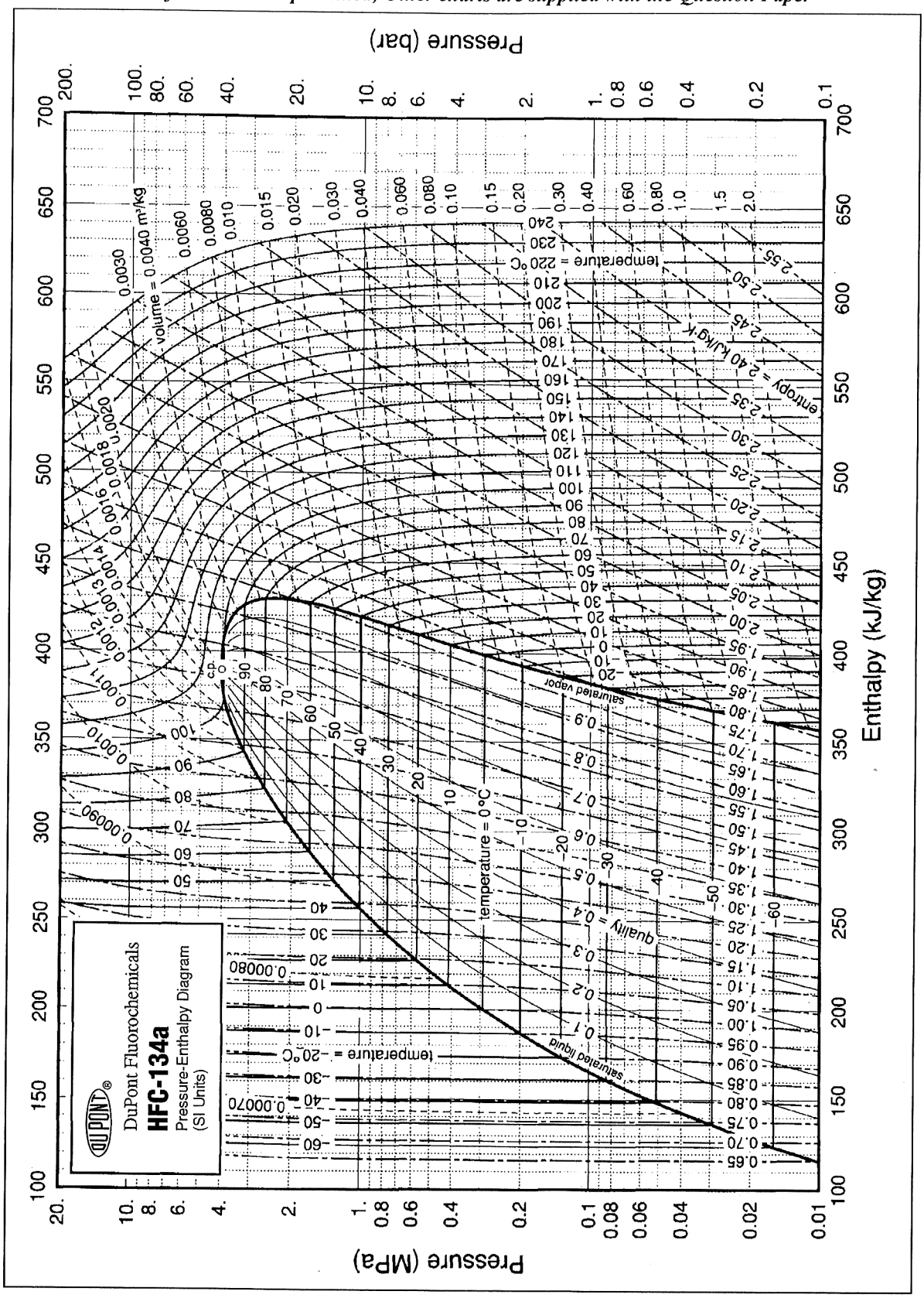

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