Ref. No. Ex/PE/PC/B/T/213/2023

B. POWER ENGINEERING 2ND YEAR FIRST SEMESTER EXAMINATION 2023

SUBJECT: **ENGINEERING THERMODYNAMICS**

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

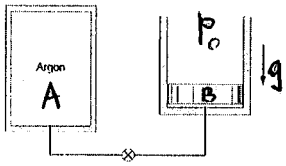
***Use of Steam Table permitted; Other charts are supplied with the Question Paper***

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

1.

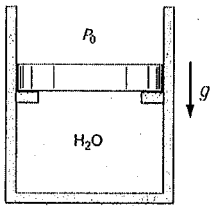
a. Give the thermodynamic definitions of Heat and Work. Cite their major difference from Internal Energy of a system. **4**

b. A 400-L tank *A* contains argon gas at 250 kPa and 30°C. Cylinder *B*, having a frictionless piston of such mass that a pressure of 150 kPa will float it, is initially empty. The valve is opened, and argon flows into *B* and eventually reaches a uniform state of 150 kPa and 30°C throughout. What is the work done by the argon? **16**




**OR**

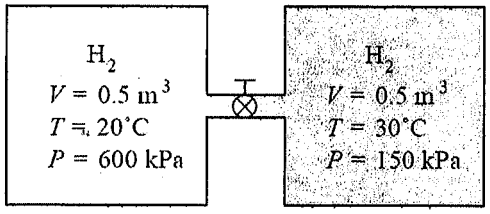
a. 10 kg of water in a piston/cylinder arrangement exists as wet steam at 100 kPa, with a quality of 50%. It is now heated so that the volume becomes three times the original. The mass of the piston is such that a cylinder pressure of 200 kPa will float it (see Fig. on the right). Find (a) the final temperature and volume of the water, (b) the heat supplied and (c) the work done by the system. **15**




b. Show that for steam the $p$ = constant lines on Mollier diagram are straight lines. Why does the slope of the lines increase as the steam is superheated? **5**

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

**2.** A 0.5 $m^3$ rigid tank containing hydrogen at 20°C and 600 kPa is connected by a valve to another 0.5 $m^3$ rigid tank that holds hydrogen at 30°C and 150 kPa. Now the valve is opened and the system is allowed to reach thermal equilibrium with the surroundings, which are at 15°C. Determine (a) the final pressure in the tank, (b) heat transferred to the surroundings, and (c) entropy generated in the process **20**




**3.**

**a.** Write down the Kelvin Planck and Clausius statements and show that they are equivalent. **6**

**b.** A fully reversible cycle receives 2500 kJ of heat at a mean temperature of 900 K. What would be the mean temperature of heat rejection if it rejects 1500 kJ of heat? **4**

**c.** A Carnot heat engine receives heat from a reservoir at 927°C at a rate of 840 kJ/min and rejects the waste heat to the ambient air at 27°C. The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at -5°C and transfers it to the same ambient air at 27°C. Determine (a) the maximum rate of heat removal from the refrigerated space and (b) the corresponding total rate of heat rejection to the ambient air.

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**4.**

**a.** Write the entropy equation for an open system and explain what each term means. **5**

**b.** A well-insulated, shell-and-tube heat exchanger is used to heat water (Cp = 4.18 kJ/kg K) in the tubes from 20 to 70°C at a rate of 4.5 kg/s. Heat is supplied by hot oil (Cp = 2.30 kJ/kg K) that enters the shell side at 170°C at a rate of 10 kg/s. Disregarding any heat loss from the heat exchanger, determine (a) the exit temperature of the oil and (b) the rate of entropy generation in the heat exchanger. **15**

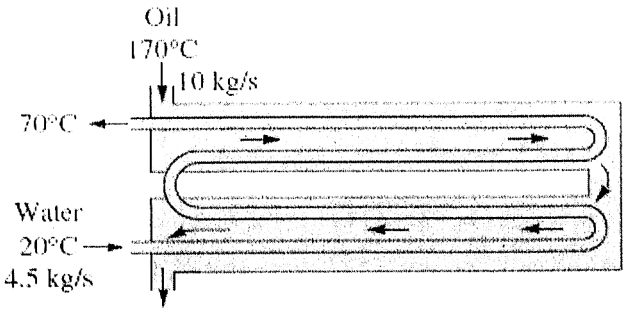


**Fig. P4c**

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

**5.**

**a.** Why is reheating done in a vapor power cycle? State the effects of reheating on cycle efficiency, work ratio and specific steam consumption. **5**

**b.** A 210 MW (net) ideal reheat cycle operates with a main steam parameters of 150 bar, 550°C and hot reheat steam parameters of 30 bar, 550°C. The condenser back pressure is maintained at 0.08 bar. Draw a neat sketch and the T-s and h-s diagrams of the cycle. Evaluate (i) the heat rate, (ii) work ratio, (iii) steam flow rate, and (iv) second-law efficiency. **20**

**6.**

a. A spark-ignition engine receives air at 10°C, 100 kPa, having a compression ratio of 9:1. The heat addition by combustion gives the highest temperature as 2500 K. Use cold air properties to find the highest cycle pressure, the specific energy added by combustion, and the mean effective pressure. **10**

**b.** A simple Brayton cycle operates with a temperature ratio of 4 and pressure ratio of 10. Find the cycle efficiency and work ratio. **7**

**c.** A diesel engine has an inlet at 95 kPa, 300 K, and a compression ratio of 20:1. The combustion releases 1300 kJ/kg. Find the temperature after combustion using cold air properties. **8**

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

7.

a. What is the function of expansion valve in a vapor compression refrigeration cycle? **3**

**OR**

Find the dew point and partial pressure of water vapor in atmospheric air at 30°C and 50% relative humidity. **3**

b. The airconditioning system for the instrument panel room of a power plant receives a steady flow of 1.5 $m^3/s$ of plant air at 35°C and 70% RH, and sends the conditioned air to the control room at 25°C and 40% RH. Find the refrigeration capacity and sensible heating needed for the cooling and dehumidification system. Also estimate the flow rate of wter dripping out of the airconditioning system. **12**

**OR**

The air conditioner in a car uses R-134a and the compressor power input is 1.5 kW, bringing the R-134a from 201.7 kPa to 1200 kPa by compression. The cold space is a heat exchanger that cools 30°C atmospheric air from the outside down to 10°C and blows it into the car. What is the mass flow rate of the R-134a, and what is the low temperature heat-transfer rate? What is the mass flow rate of air at 10°C? Use the enclosed property chart for R-134. **12**

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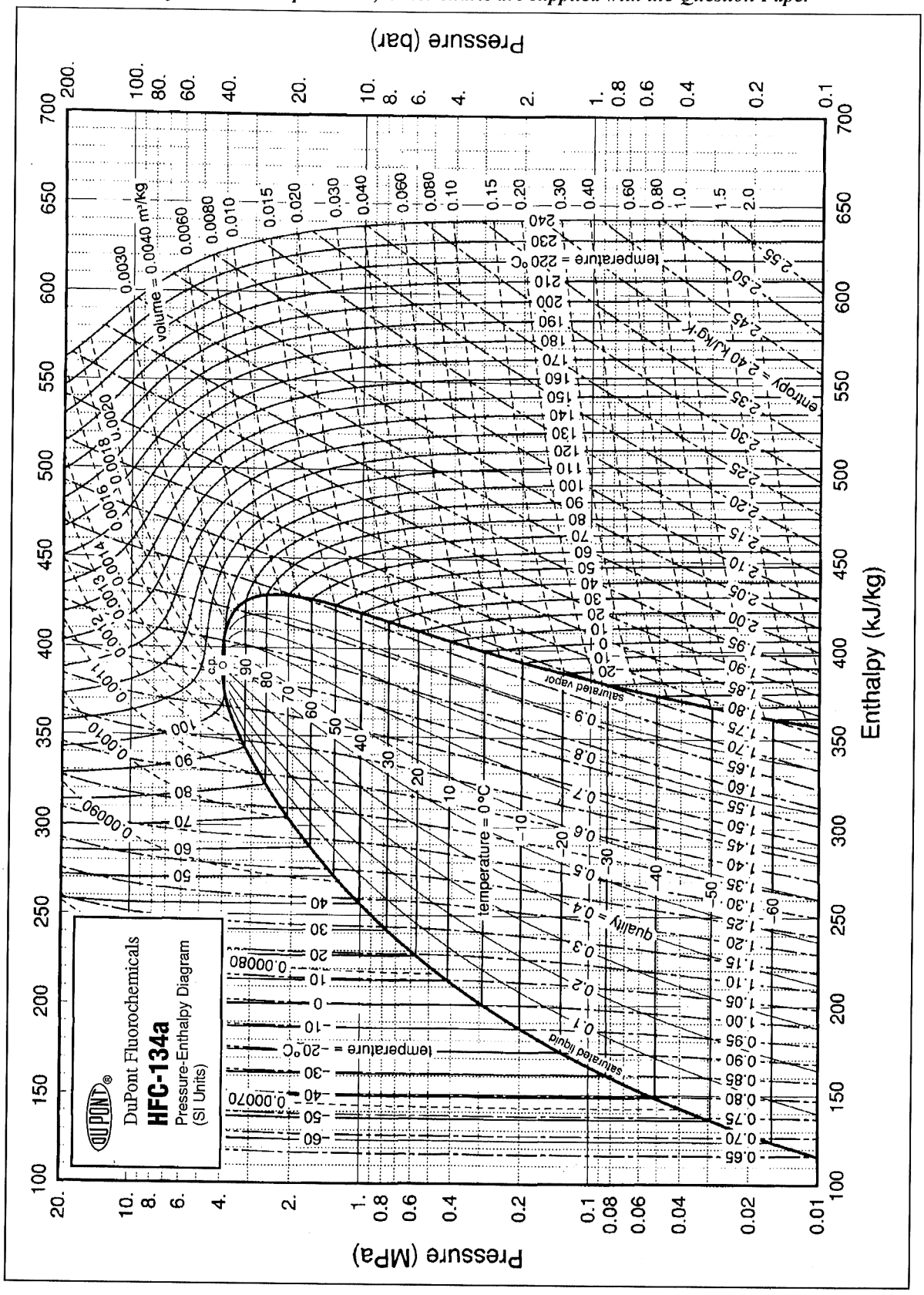

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Psychrometric Chart (at 1 atm)