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B. POWER ENGINEERING 2ND YEAR FIRST SEMESTER SUPLEMENTARY EXAMINATION 2023

SUBJECT: ***ENGINEERING THERMODYNAMICS***

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

Use of Steam Table permitted; Air Table is supplied with the Question Paper

CO 1: Answer any <u>one</u> questions 20 marks

1.

a. Define heat and work and discuss their similarities and dissimilarities **5**

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? Assume C_p = 1.005 kJ/kgK for air. 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? Neatly draw the processes in p-v plot. Assume γ=1.4 for air. **15**

2.

a. Define a reversible and irreversible process. Give examples of each. **5**

b. A closed adiabatic system with a weightless piston at the top contains air at 100 kPa, 220°C. The ambient pressure is also 100 kPa (area of piston : 100 cm^2; volume at state 1: 0.1 m^3). Suddenly, a weight of 1 kN is placed and system reaches state 2. a) Sketch the process on P-V diagram. (c) Find the work done in the process, and b) Determine P_2, V_2 and T_2. **12**

c. What do you mean by critical temperature and pressure of water? State their values. **3**

CO 2: Answer any <u>one</u> questions 20 marks

3.

a. State the first law of thermodynamics for a closed system. What do you mean by PMM-1? **4**

b. An ideal gas of molecular weight 100 executes an internally reversible cycle as described in Fig 3b. Find (i) The heat addition to the cycle, (ii) The net work done, (iii) Efficiency/ COP, (iv) $\oint TdS$, and (v) ΔH during process 1 -2. Assume γ=1.5 **16**

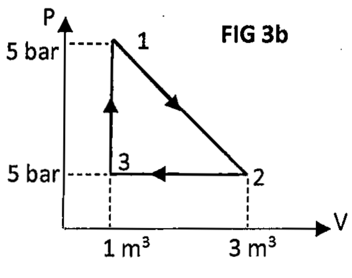

FIG 3b

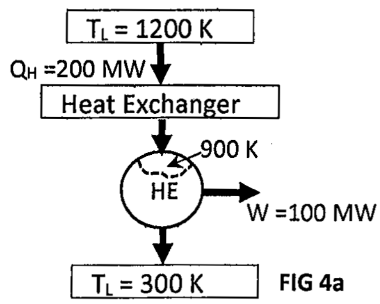

FIG 4a

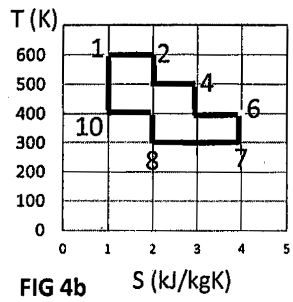

FIG 4b

4.

a. A 100 MW power plant receives 200 MW heat from a 1200 K reservoir; but as the heat reaches the cycle through a heat exchanger the temperature drops to 900 K. The cycle rejects heat to 300 K atmosphere (see Fig 4a). Estimate the entropy generation within and outside the cycle. **15**

b. Find the efficiency of a power plant cycle whose T-s diagram is described in Fig 4b **5**

[Turn over

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CO 3: Answer any <u>two</u> questions 40 marks

5.

a. 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? **10**

b. A cooler in an air conditioner sucks in 0.5 kg/s of air at 35°C and delivers it at 5°C, both at 101 kPa. It then mixes the output with a flow of 0.25 kg/s air at 20°C and 101 kPa, sending the combined flow into a duct. Find the total heat transfer in the cooler and the temperature in the duct flow. Assume C_p=1.004 kJ/kg and γ=1.4 for air. **10**

6.

a. A 100 MW steam power plant operates on a Rankine cycle with main steam temperature and pressure of 550 °C and 130 bar, while the condenser operates at a back pressure of 0.1 bar. Assuming the turbine expansion to be isentropic and neglecting the pump work, find the cycle heat rate, specific steam consumption and the heat rejected through the condenser. **10**

b. An 100 MW gas turbine plant operates in an ideal Brayton cycle with a pressure ratio of 10 and a temperature ratio of 3. If the combustion chamber has an efficiency of 99% and it burns a fuel with calorific value of 21000 kJ/kg, find the fuel consumption of the power plant. **10**

7.

a. What do you mean by "knocking" in diesel cycles? How is it avoided? **5**

b. An ideal Otto cycle is operated at a compression ratio of 5 between maximum and minimum pressures of 1 and 21 bars, respectively. If the adiabatic index of air is 1.4, calculate (i) the thermal efficiency, (ii) mean effective pressure, and (iii) specific power output of the cycle. **15**

CO 4: Answer any <u>one</u> question 20 marks

8.

a. What do you mean by Tons of refrigeration? **1**

b. List out the ideal properties of a refrigerant for a vapor compression refrigeration cycle. Why only is a CFC-free refrigerants are preferred in modern refrigeration and air-conditioning systems? **3+1 = 4**

c. Refrigerant 134a is the working fluid in an ideal vapor-compression refrigeration cycle that communicates thermally with a cold region at 0 °C and a warm region at 30 °C. Saturated vapor enters the compressor at 0°C and saturated liquid leaves the condenser at 30 °C. Plot the process on representative T-s and p-h diagrams. The mass flow rate of

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the refrigerant is 0.08 kg/s. Determine (a) the compressor power, in kW, (b) the refrigeration capacity, in tons, (c) the coefficient of performance, and (d) the coefficient of performance of a Carnot refrigeration cycle operating between warm and cold regions at 30 and 0 °C, respectively. Use the enclosed property chart for R-134 **15**

9. A wet cooling tower (See Fig. P9) is to cool 60 kg/s of water from 40 to 26°C. Atmospheric air enters the tower at 1 atm with dry- and wet-bulb temperatures of 22 and 16°C, respectively, and leaves at 30°C with a relative humidity of 90 percent. Using the psychrometric chart, determine (a) the volume flow rate of air into the cooling tower and (b) the mass flow rate of the required makeup water, which also enters at 26°C. Use Psychrometric chart provided at the end of the question paper. **20 marks**

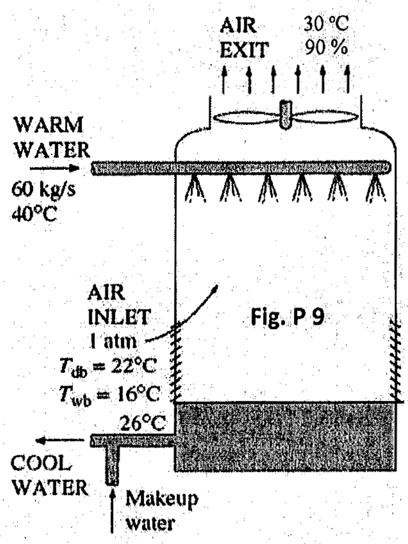

Fig. P 9

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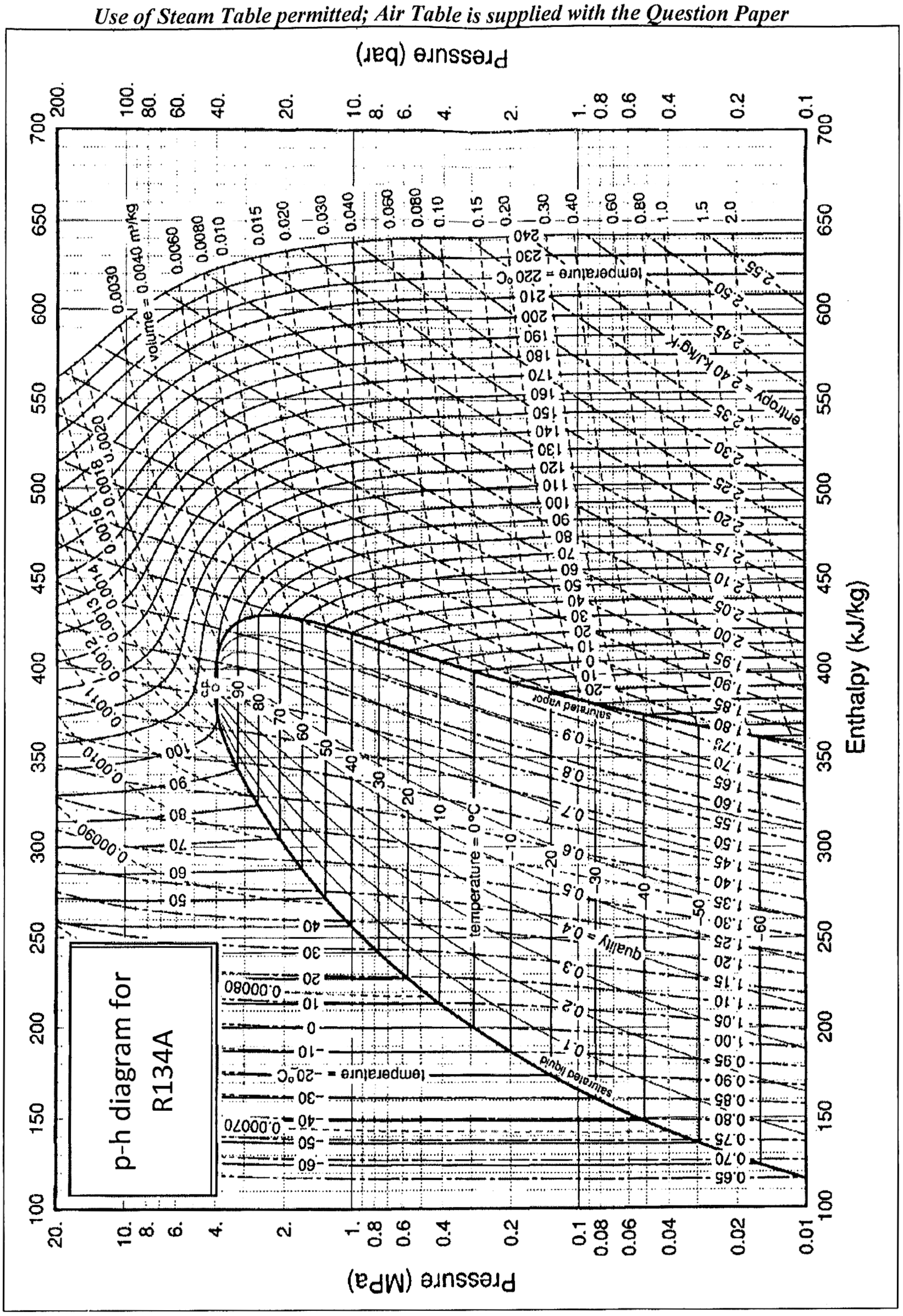

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Ideal-Gas Properties of Air, Standard Entropy at 0.1-MPa (1-Bar) Pressure

T (K)	u (kJ/kg)	h (kJ/kg)	s_T^0 (kJ/kg-K)	T (K)	u (kJ/kg)	h (kJ/kg)	s_T^0 (kJ/kg-K)
200	142.77	200.17	6.46260	1100	845.45	1161.18	8.24449
220	157.07	220.22	6.55812	1150	889.21	1219.30	8.29616
240	171.38	240.27	6.64535	1200	933.37	1277.81	8.34596
260	185.70	260.32	6.72562	1250	977.89	1336.68	8.39402
280	200.02	280.39	6.79998	1300	1022.75	1395.89	8.44046
290	207.19	290.43	6.83521	1350	1067.94	1455.43	8.48539
298.15	213.04	298.62	6.86305	1400	1113.43	1515.27	8.52891
300	214.36	300.47	6.86926	1450	1159.20	1575.40	8.57111
320	228.73	320.58	6.93413	1500	1205.25	1635.80	8.61208
340	243.11	340.70	6.99515	1550	1251.55	1696.45	8.65185
360	257.53	360.86	7.05276	1600	1298.08	1757.33	8.69051
380	271.99	381.06	7.10735	1650	1344.83	1818.44	8.72811
400	286.49	401.30	7.15926	1700	1391.80	1879.76	8.76472
420	301.04	421.59	7.20875	1750	1438.97	1941.28	8.80039
440	315.64	441.93	7.25607	1800	1486.33	2002.99	8.83516
460	330.31	462.34	7.30142	1850	1533.87	2064.88	8.86908
480	345.04	482.81	7.34499	1900	1581.59	2126.95	8.90219
500	359.84	503.36	7.38692	1950	1629.47	2189.19	8.93452
520	374.73	523.98	7.42736	2000	1677.52	2251.58	8.96611
540	389.69	544.69	7.46642	2050	1725.71	2314.13	8.99699
560	404.74	565.47	7.50422	2100	1774.06	2376.82	9.02721
580	419.87	586.35	7.54084	2150	1822.54	2439.66	9.05678
600	435.10	607.32	7.57638	2200	1871.16	2502.63	9.08573
620	450.42	628.38	7.61090	2250	1919.91	2565.73	9.11409
640	465.83	649.53	7.64448	2300	1968.79	2628.96	9.14189
660	481.34	670.78	7.67717	2350	2017.79	2692.31	9.16913
680	496.94	692.12	7.70903	2400	2066.91	2755.78	9.19586
700	512.64	713.56	7.74010	2450	2116.14	2819.37	9.22208
720	528.44	735.10	7.77044	2500	2165.48	2883.06	9.24781
740	544.33	756.73	7.80008	2550	2214.93	2946.86	9.27308
760	560.32	778.46	7.82905	2600	2264.48	3010.76	9.29790
780	576.40	800.28	7.85740	2650	2314.13	3074.77	9.32228
800	592.58	822.20	7.88514	2700	2363.88	3138.87	9.34625
850	633.42	877.40	7.95207	2750	2413.73	3203.06	9.36980
900	674.82	933.15	8.01581	2800	2463.66	3267.35	9.39297
950	716.76	989.44	8.07667	2850	2513.69	3331.73	9.41576
1000	759.19	1046.22	8.13493	2900	2563.80	3396.19	9.43818
1050	802.10	1103.48	8.19081	2950	2613.99	3460.73	9.46025
1100	845.45	1161.18	8.24449	3000	2664.27	3525.36	9.48198

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Psychrometric Chart (at 1 atm)