B. POWER ENGINEERING 2ND YEAR FIRST SEMESTER EXAMINATION 2019

SUBJECT: **ENGINEERING THERMODYNAMICS I**

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

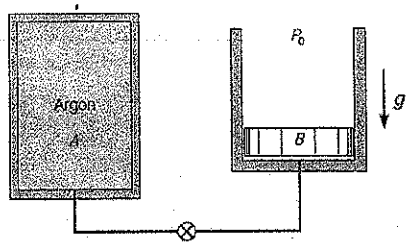
Use of Steam Table permitted; Air Table is supplied with the Question Paper

Part I: Answer any <u>one</u> questions 20 marks

1.

a. What do you mean by a reversible and an irreversible process? State the factors that lead to irreversibility in a system. **2+3=5**

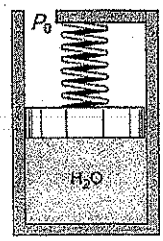
b. A 400-L tank *A* contains argon gas at 250 kPa and 30◦C. Cylinder *B*, having a frictionless piston of such mass that a pressure of 150 kPa will float it, is initially empty. The valve is opened, and argon flows into *B* and eventually reaches a uniform state of 150 kPa and 30◦C throughout. What is the work done by the argon? **15**



2.

a. A piston/cylinder assembly contains 1 kg of liquid water at 20◦C and 300 kPa. There is a linear spring mounted on the piston such that when the water is heated, the pressure reaches 3 MPa with a volume of 0.1 m^3. (i) Find the final temperature. (ii) Plot the process on the p-υ and *T-s* diagrams. (c) Find the work in the process. Assume R_{air} = 0.287 kJ/kgK and γ=1.4. **15**

b. Show that the of p = constant lines in Mollier diagram are straight lines in the wet region and the slopes of the lines increase with temperature **5**

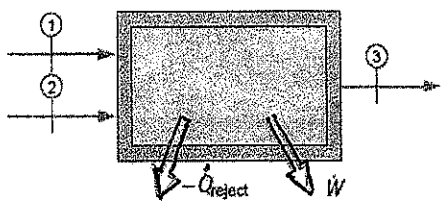


Part II: Answer any <u>one</u> questions 20 marks

3.

a. An empty cylinder of volume V is connected to a methane gas refilling pipeline through a stop valve. The gas refilling pipeline is maintained at a pressure p and temperature T. The stop valve is crack-opened when the gas fills up the cylinder to pressure p. Write the energy conservation equation if the heat transfer during gas-refilling process is negligible. **5**

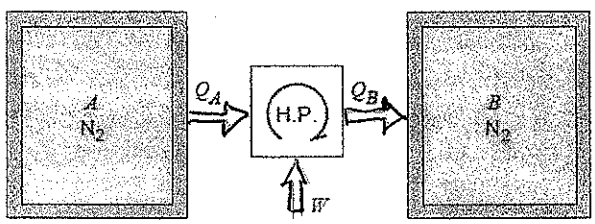
b. Two steady flows of air enter a control volume. One is a 0.025 kg/s flow at 350 kPa, 150 ◦C, state 1, and the other enters at 450 kPa, 15 ◦C, state 2. A single flow exits at 100 kPa, −40 ◦C, state 3. The control volume ejects 1 kW heat to the surroundings and produces 4 kW of power output. Neglect kinetic energies and determine the mass flow rate at state 2. Use Air Table. **15**



4.

a. State Kelvin Planck and Clausius statements, and show that they are equivalent. **5**

b. Each of the two rigid tanks shown in the following figure contain 10 kg of N_2 gas at 1000 K, 500 kPa. They are now thermally connected to a reversible heat pump, which heats one and cools the other with no heat transfer to the surroundings. When one tank is heated to 1500 K, the process stops. Find the final (P, T) in both tanks and the work input to the heat pump, assuming constant heat capacities $C_{p,N2}$ = 0.92 kJ/kgK. **15**



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Part III: Answer any <u>two</u> questions 40 marks

5.

a. Draw a neat sketch of a single-acting reciprocating air compressor with its drive and label the major components **5**

b. A single-stage, single-acting reciprocating air compressor delivers air at 7 bar while its suction is drawn at 1 bar and 27°C. The cylinder has a bore of 35 cm and stroke of 40 cm, and it runs at 360 rpm. Determine the FAD, theoretical power consumed by the compressor and brake power, if n=1.3 and $\eta_{mechanical}$ = 90%. Assume R_{air} = 0.287 kJ/kgK and γ=1.4. **15**

6.

a. A gearbox assembly of a truck receives 1kN.m of torque in the driving shaft (that connects the engine and the gearbox) and transmits 0.95 kN.m to its driven shaft (gear box to the axel). Both the shafts are rotating at 600 rpm. The outer wall surface of the gearbox is maintained at 77 °C, while the ambient is at 300 K. What are the entropy generation rates (i) in the gearbox assembly, and (ii) outside? **10**

b. An air conditioner cools a house at T_L =20◦C with a maximum of 1.2 kW power input. The house gains energy as $\dot{Q} = 0.6(T_H - T_L)$[kW] and the refrigeration COP is $\beta = 0.6\ \beta_{CARNOT}$. Find the maximum outside temperature, T_H, for which the air conditioner unit provides sufficient cooling. **10**

7.

a. Write down the entropy transport equation for an open system, and explain the significance of each term. **5**

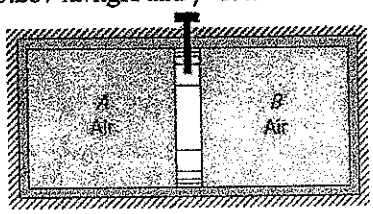
b. Steam enters a non-adiabatic turbine in a steady state steady flow process at 100 bar as saturated vapor and undergoes irreversible expansion to a quality of 0.9 at 1 bar. The heat loss to the ambient at 300 K is 50 kJ/kg of steam. Determine: (a) the work output (b) entropy generation due to the irreversibilities. **15**

Part IV: Answer any <u>one</u> question 20 marks

8.

a. What do mean by thermomechanical exergy of a nonflow system? Write the expression of specific nonflow themomechanical exergy. **5**

b. An insulated cylinder is divided into two parts A and B of 1 m^3 each by an initially locked piston, as shown in the following figure. Side A has air at 200 kPa, 300 K, and side B has air at 1.0 MPa, 1000 K. The piston is now unlocked so that it is free to move, and it conducts heat so that the air comes to a uniform temperature $T_A = T_B$. Find the mass in both A and B and the final T and P, and the exergy destroyed in the process. Assume the ambient temperature to be 300 K and 1 bar. Use Air Table or assume R_{air} = 0.287 kJ/kgK and γ=1.4. **15**



9.

a. Write down the exergy transport equation for an open system and define what each term mean. **5**

b. An air compressor takes air in at the state of the surroundings, 100 kPa, 300 K. The air exits at 400 kPa, 200◦C, at the rate of 2 kg/s. Determine the minimum compressor work input. If the second law efficiency of the compressor is 80%, determine its isentropic efficiency. Use Air Table **15**

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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