國立清華大學106學年度碩士班考試入學試題

系所班組別：工程與系統科學系碩士班 乙組(0527)

考試科目（代碼）：熱力學 (2702)

 ＊請在【答案卷】作答

1. True/False questions: (please answer: ○ or ╳) 【20%】
   (1) A system with uniform temperature is called mechanical equilibrium. (1%)
   (2) For an open system, mass and energy can flow in/out freely. (1%)
   (3) For a closed system, both heat and work can transfer out. (1%)
   (4) During an adiabatic process, temperature is constant. (1%)
   (5) During an isobaric process, pressure is constant. (1%)
   (6) During an isochoric process, volume is constant. (1%)
   (7) If this power cycle is irreversible, the cycle efficiency can be determined by: $\eta_{th} = 1 - \frac{T_C}{T_H}$, where T_c is cold reservoir temperature, T_H is hot reservoir temperature(1%)
   (8) Intensive properties may change with time and position. (1%)
   (9) Entropy is a state function only under a reversible process, and therefore for an irreversible process, entropy becomes a path function. (1%)
   (10) Work and heat are properties. (1%)
   (11) Entropy cannot increase if there is no heat transfer across the system boundary. (1%)
   (12) Extensive properties can be directly measured by a local measuring probe. (1%)
   (13) Thermal efficiency (η) is always ≤ 1. (1%)
   (14) For compressor W<0; $P_e > P_i$, where P_e, P_i represented exit pressure and inlet pressure (1%)
   (15) Based on the definition of Coefficient of Performance (C.O.P.) of an ideal heat pump (γ), γ is always ≥ 1. (1%)
   (16) For a closed system undergoing a cycle, the net work output equals to the net heat input. (1%)
   (17) For reversible heat engine, $\oint \left(\frac{\delta Q}{T}\right)_{rev} < 0$? (1%)
   (18) For reversible heat engine, $\oint \delta Q_{rev} \geq 0$ (1%)
   (19) For turbine W>0; $P_e < P_i$, where P_e, P_i represented exit pressure and inlet pressure (1%)
   (20) Is it true for $A = U + TS$ (1%)

2. Fig. 1 shows a simple vapor power plant operating at steady state with water as the working fluid. Data at key locations are giving on the figure. The mass flow rate of the water circulating through the component is 109Kg/s. Stray heat transfer and kinetic and potential energy effects can be ignored. Assume the friction pressure drop in steam generator and condenser can be neglected as well. Assume the average specific volume of the liquid water through the pump is 1.4×10^{-3}(m^3/Kg), 1bar=10^5 Pa 【20%】

Determine:

(a) Evaluate P_4 (1%) and P_2 in bar (1%)

(b) Enthalpy on state 2 h_2 in KJ/Kg (1%), entropy on state 2 s_2 in KJ/Kg,K (1%)

(c) The mass flow rate of the cooling water, in Kg/s (1%)

(d) The turbine work W_t in KJ/s (1%), the pump work W_p in KJ/s (1%)

(e) Evaluate T_4 (1%), s_4 KJ/Kg,K (1%), h_4 in KJ/Kg (1%) and $\dot{Q}_{in}$ in KJ/s (1%)

(f) Thermal efficiency η_{th} of the cycle (1%)

(g) The rate of entropy production, each in KW/K, for the turbine (1%), condenser (1%)

(h) If 4s represented the isentropic state 4 if the pump can be assumed reversible and adiabatic, try to evaluate the temperature T_{4s} (1%), and isentropic enthalpy h_{4s} at state 4s in KJ/Kg (1%).

(i) If 2s represented the isentropic state 2 and if the turbine can be assumed reversible and adiabatic, try to evaluate isentropic quality x_{2s} (1%) and isentropic enthalpy h_{2s} (1%) at state 2s in KJ/Kg

(j) The Isentropic Efficiencies of pump η_p (1%) and Isentropic Efficiencies of turbine η_t (1%)

Properties of superheated water vapor		
P=100bar=10.0MPa; T_{sat}=311.06°C		
T(°C)	h (KJ/Kg)	s (KJ/Kg.K)
480	3321.4	6.5282
520	3425.1	6.6622
560	3526.0	6.7864

Properties of compressed liquid water			
P=100bar=10.0MPa; T_{sat}=311.06°C			
T (°C)	$v\times10^3$ m^3/Kg	h (KJ/Kg)	s (KJ/Kg.K)
20	1.3	93.33	0.2945
40	1.4	176.38	0.5686
80	1.5	342.83	1.0688

Properties of saturated water

P bar	T ℃	$v_f \times 10^3$ m^3/Kg	V_g m^3/Kg	h_f KJ/Kg	h_{fg} KJ/Kg	h_g KJ/Kg	s_f KJ/Kg.K	s_g KJ/Kg.K
0.04	28.96	1.04	34.82	121.46	2432.9	2554.4	0.4226	8.4746
0.06	36.16	1.06	23.739	151.53	2415.9	2567.4	0.5210	8.3304
0.08	41.51	1.08	18.101	173.88	2403.1	2577.0	0.5926	8.287
0.1	45.81	1.10	14.674	191.83	2392.8	2584.7	0.6493	8.1502
0.2	60.06	1.12	7.649	251.40	2358.3	2609.7	0.8320	7.9085
0.3	69.1	1.14	5.229	289.23	2336.1	2625.3	0.9439	7.7686
0.4	75.87	1.16	3.993	317.58	2319.2	2636.8	1.0259	7.6700
0.5	81.33	1.18	3.24	340.49	2305.4	2645.9	1.0910	7.5939

Properties of saturated water

T ℃	P bar	$V_f \times 10^3$ m^3/Kg	V_g m^3/Kg	h_f KJ/Kg	h_{fg} KJ/Kg	h_g KJ/Kg	s_f KJ/Kg.K	s_g KJ/Kg.K
20	0.02339	1.02	57.791	83.96	2454.1	2538.1	0.2966	8.6672
25	0.03169	1.03	43.36	104.89	2442.3	2547.2	0.3674	8.5580
30	0.04246	1.04	32.894	125.79	2430.5	2556.3	0.4369	8.4533
35	0.05628	1.05	25.216	146.68	2418.6	2505.3	0.5053	8.3531
40	0.07384	1.07	19.523	167.57	2406.7	2574.3	0.5725	8.2570

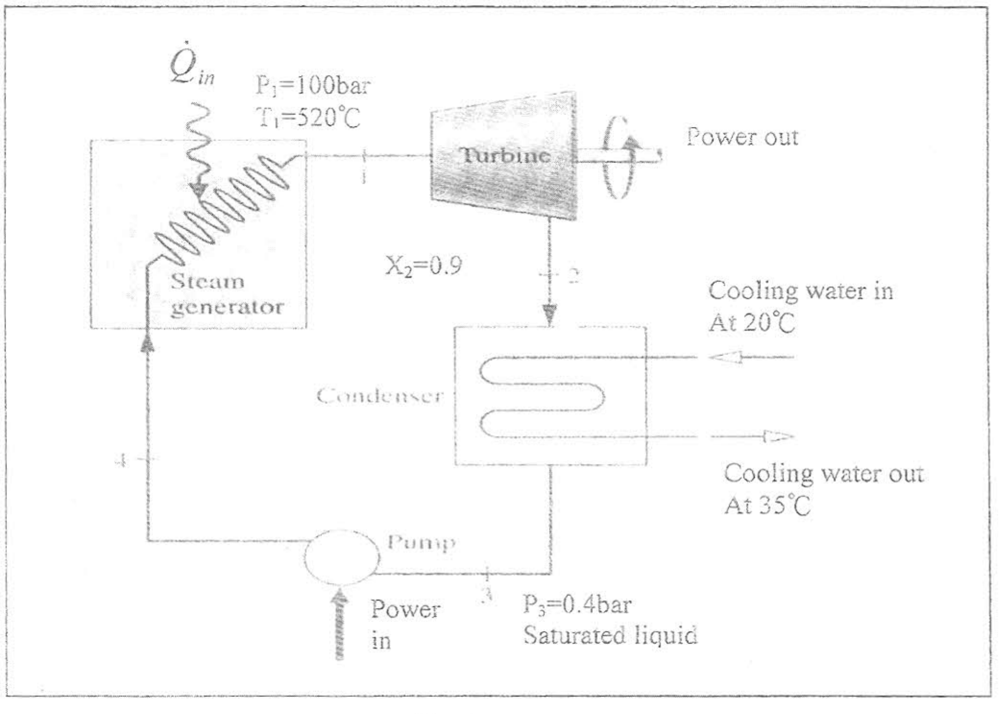

Fig. 1

3. Water is from state (10) to state (3). Show as in following figure 2. Assume water volume expansivity α_p and Isothermal compressibility β_T are constant.

Define: expansivity is constant: $\alpha_p = \frac{1}{V_f}\left(\frac{\partial V_f}{\partial T}\right)_p$,

Isothermal compressibility: $\beta_T = -\frac{1}{V}(\frac{\partial V}{\partial P})_T$

As the following figure, Given known data: $V_{f,3}, V_{f,10,}$ where $V_{f,3}, V_{f,10}$ represented liquid specific volume at state 3 and state 10 respectively. T_3, T_8, P_3, P_{10}, α_p, β_T are known, C_f is the liquid specific heat which is known as well【20%】

Determine from the given date, evaluate the following:

(a) Evaluate internal energy change $\Delta u_{10,3}$ from state 10 to state 3 (4%)
Assume $\int PdV$ can be neglected

(b) Evaluate enthalpy change $\Delta h_{10,3}$ from state 10 to state 3 (4%)

(c) Evaluate the entropy change $\Delta S_{10,3}$ from state 10 to state 3 (4%).

(d) Evaluate the entropy change $\Delta S_{3,8}$ from state 3 to state 8 (4%).

(e) Evaluate the enthalpy change $\Delta u_{3,8}$ from state 3 to state 8 (4%)

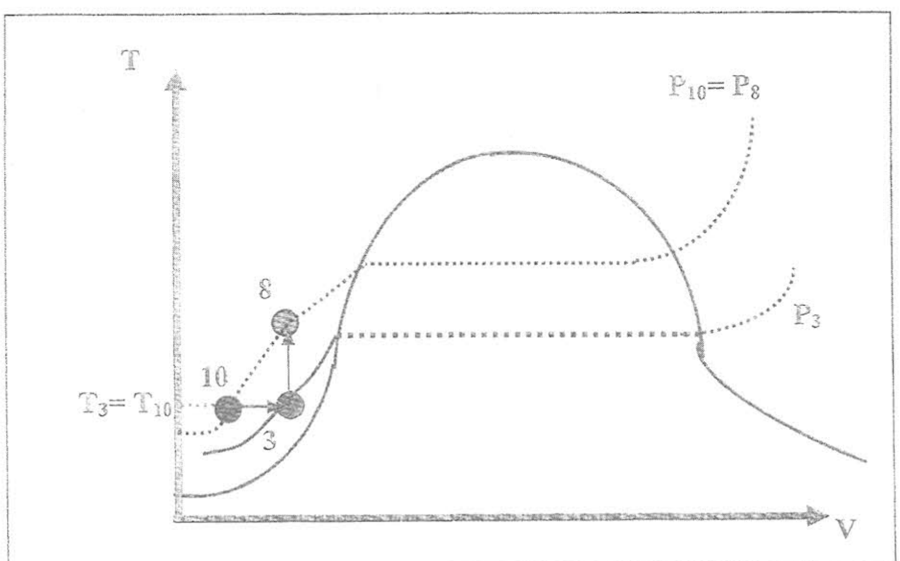

Figure 2

4. Figure 3 shows a tank having a volume of 1.021 m^3 initially contains water as a two-phase liquid-vapor mixture at 300℃ and a quality of 0.8. Saturated water vapor at 300℃ is slowly withdrawn through a pressure regulating valve at the top of the tank as energy is transferred by heat to maintain the pressure constant in the tank. This continues until the tank is filled with saturated vapor at 300℃. Neglect all the kinetic and potential energy effects. 【20%】

You might use the following TABLE A-2 to determine:

(a) Write down the energy balance equation, for Q with function of m_1, u_1, m_2, u_2 and h_e, where m_1 is the initial mass of fluid in the tank, u_1 is the initial internal energy of the fluid in tank, m_2 is the final mass of fluid in the tank, u_2 is the final internal energy of fluid in the tank, h_e is the exit enthalpy of the fluid (3%)

(b) The specific volume at initial state in (m^3/Kg) (2%)

(c) The mass m_1 for initial state in Kg (1%)

(d) The total internal energy for initial state U_1 in KJ (3%)

(e) The mass m_2 for final state in Kg (2%)

(f) The total internal energy for final state U_2 in KJ (2%)

(g) The amount mass expelled from tank (2%)

(h) The amount of heat transfer, Q in KJ (3%).

(i) Please draw the T-S diagram from state 1 to state 2 (2%)

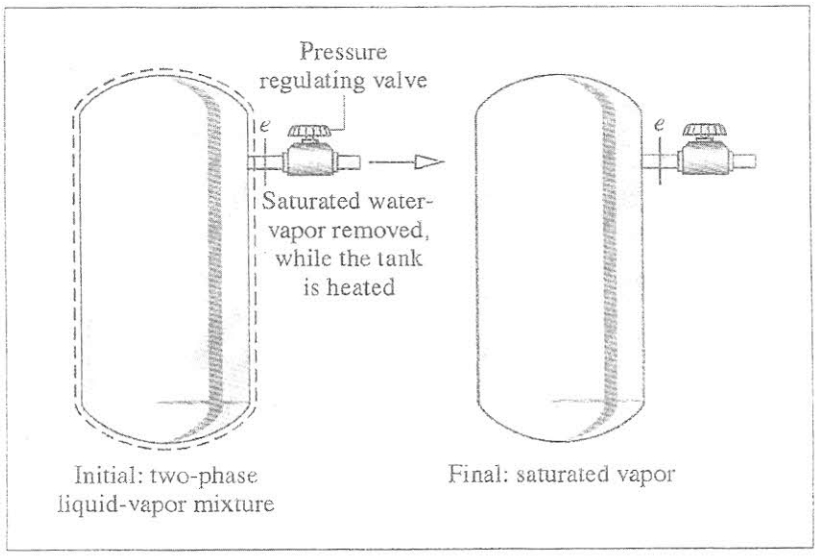

Figure 3

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TABLE A-2 (Continued)

		Specific Volume m³/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Temp °C	Press. bar	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	Temp. °C
50	.1235	1.0121	12.032	209.32	2443.5	209.33	2382.7	2592.1	.7038	8.0763	50
55	.1576	1.0146	9.568	230.21	2450.1	230.23	2370.7	2600.9	.7679	7.9913	55
60	.1994	1.0172	7.671	251.11	2456.6	251.13	2358.5	2609.6	.8312	7.9096	60
65	.2503	1.0199	6.197	272.02	2463.1	272.06	2346.2	2618.3	.8935	7.8310	65
70	.3119	1.0228	5.042	292.95	2469.6	292.98	2333.8	2626.8	.9549	7.7553	70
75	.3858	1.0259	4.131	313.90	2475.9	313.93	2321.4	2635.3	1.0155	7.6824	75
80	.4739	1.0291	3.407	334.86	2482.2	334.91	2308.8	2643.7	1.0753	7.6122	80
85	.5783	1.0325	2.828	355.84	2488.4	355.90	2296.0	2651.9	1.1343	7.5445	85
90	.7014	1.0360	2.361	376.85	2494.5	376.92	2283.2	2660.1	1.1925	7.4791	90
95	.8455	1.0397	1.982	397.88	2500.6	397.96	2270.2	2668.1	1.2500	7.4159	95
100	1.014	1.0435	1.673	418.94	2506.5	419.04	2257.0	2676.1	1.3069	7.3549	100
110	1.433	1.0516	1.210	461.14	2518.1	461.30	2230.2	2691.5	1.4185	7.2387	110
120	1.985	1.0603	0.8919	503.50	2529.3	503.71	2202.6	2706.3	1.5276	7.1296	120
130	2.701	1.0697	0.6685	546.02	2539.9	546.31	2174.2	2720.5	1.6344	7.0269	130
140	3.613	1.0797	0.5089	588.74	2550.0	589.13	2144.7	2733.9	1.7391	6.9299	140
150	4.758	1.0905	0.3928	631.68	2559.5	632.20	2114.3	2746.5	1.8418	6.8379	150
160	6.178	1.1020	0.3071	674.86	2568.4	675.55	2082.6	2758.1	1.9427	6.7502	160
170	7.917	1.1143	0.2428	718.33	2576.5	719.21	2049.5	2768.7	2.0419	6.6663	170
180	10.02	1.1274	0.1941	762.09	2583.7	763.22	2015.0	2778.2	2.1396	6.5857	180
190	12.54	1.1414	0.1565	806.19	2590.0	807.62	1978.8	2786.4	2.2359	6.5079	190
200	15.54	1.1565	0.1274	850.65	2595.3	852.45	1940.7	2793.2	2.3309	6.4323	200
210	19.06	1.1726	0.1044	895.53	2599.5	897.76	1900.7	2798.5	2.4248	6.3585	210
220	23.18	1.1900	0.08619	940.87	2602.4	943.62	1858.5	2802.1	2.5178	6.2861	220
230	27.95	1.2088	0.07158	986.74	2603.9	990.12	1813.8	2804.0	2.6099	6.2146	230
240	33.44	1.2291	0.05976	1033.2	2604.0	1037.3	1766.5	2803.8	2.7015	6.1437	240
250	39.73	1.2512	0.05013	1080.4	2602.4	1085.4	1716.2	2801.5	2.7927	6.0730	250
260	46.88	1.2755	0.04221	1128.4	2599.0	1134.4	1662.5	2796.6	2.8838	6.0019	260
270	54.99	1.3023	0.03564	1177.4	2593.7	1184.5	1605.2	2789.7	2.9751	5.9301	270
280	64.12	1.3321	0.03017	1227.5	2586.1	1236.0	1543.6	2779.6	3.0668	5.8571	280
290	74.36	1.3656	0.02557	1278.9	2576.0	1289.1	1477.1	2766.2	3.1594	5.7821	290
300	85.81	1.4036	0.02167	1332.0	2563.0	1344.0	1404.9	2749.0	3.2534	5.7045	300
320	112.7	1.4988	0.01549	1444.6	2525.5	1461.5	1238.6	2700.1	3.4480	5.5362	320
340	145.9	1.6379	0.01080	1570.3	2464.6	1594.2	1027.9	2622.0	3.6594	5.3357	340
360	186.5	1.8925	0.006945	1725.2	2351.5	1760.5	720.5	2481.0	3.9147	5.0526	360
374.14	220.9	3.155	0.003155	2029.6	2029.6	2099.3	0	2099.3	4.4298	4.4298	374.14

Source: Tables A-2 through A-5 are extracted from J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables*, Wiley, New York, 1969.

5. (a) Please prove work ($\delta W=PdV$) is path function by using mathematic method (5%)

   Hint: prove work is inexact differential equation

   (b) What is isentropic process (1%) and gives the requirement for the isentropic (2%)

   (c) Which thermal property is constant at Throtting process (2%)

   (d) Write down Joule –Thomson coefficient with function of (P,V,T,C_p) (2%)

   (e) Write down the Clausius Inequality equation (2%)

   (f) Given Two temperature reservoir T_H and T_L represent high temperature and low temperature respectively, please draw P-V diagram for the Carnot Ideal Gas Power Cycles, also please mark Q_H (heat absorb at high temperature reservoir) and Q_L (heat reject at low temperature reservoir) and the thermodynamic behavior (such as isothermal compression etc.,) on each step. (6%)