注意：考試開始鈴響前，不得翻閱試題，
並不得書寫、畫記、作答。

國立清華大學 113 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
乙組

科目代碼：3002

考試科目：熱力學

—作答注意事項—

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「▼ 由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「國立清華大學試場規則及違規處理辦法」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 113 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(0530)

考試科目（代碼）：熱力學 (3002)

 *請在【答案卷】作答

Problem 1 (9 pts).

Please fill in (1) through (6) in the following description.

a. Energy can be transferred by (1), (2), and (3).
b. Entropy can be transferred by (4) and (5), and generated by (6).

Problem 2 (10 pts)

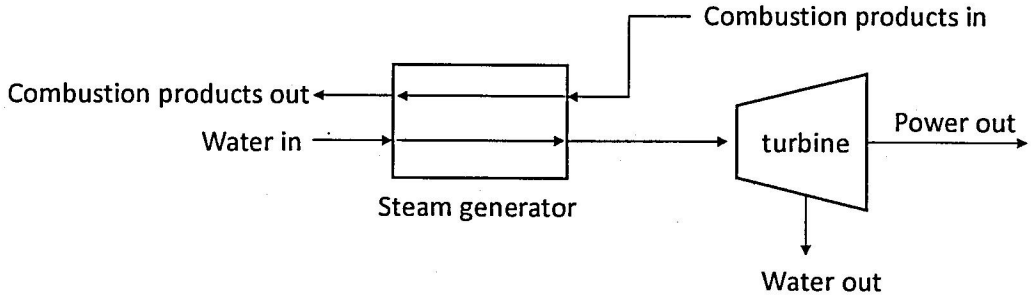
A piston-cylinder device contains helium gas initially at 150 kPa, 20 °C, and 0.5 m^3. The helium is now compressed to 400 kPa and 140 °C in a polytropic process. Determine the heat loss or gain during this process. C_v = 3.12 kJ/kg·K and R = 2.08 kJ/ kg·K for helium.

Problem 3 (12 pts)

A system that utilizes the recycled heat from combustion products to generate steam is shown below. At steady state, combustion products enter and exit the steam generator at 478K and 400K, respectively, with an entering flow rate of 70 kg/s. The pressure of the steam generator remains 100 kPa throughout the process. A separate water stream enters the steam generator at 310K and 0.3 MPa, with an entering flow rate of 2 kg/s. At the exit of the turbine, the pressure is 10 kPa, and the quality is 93%. Assume the steam generator and the turbine are adiabatic, and the potential and kinetic energy of flowing streams can be ignored. The combustion products can be modeled as air and ideal gas (C_p = 1.00 kJ/kg·K for air). Tables for water properties are listed in Appendix I.

Please determine:

a. The inlet temperature of the turbine.
b. The power output of the turbine.



Problem 4 (11 pts)

Starting from the Tds relation, derive the first isentropic relation of ideal gas under constant specific heat assumption. The first isentropic relation is $\left(\frac{T_2}{T_1}\right) = \left(\frac{V_2}{V_1}\right)^{k-1}$.

Problem 5 (8 pts)
A refrigerator with a coefficient of performance of 6 transfer heat from a cold region of -20°C to a hot region of 30 °C. Calculate the total entropy change of the process. Will the refrigerator satisfy the second law?

Appendix I:

Saturated water—Temperature table

		Specific volume, m³/kg		*Internal energy,* kJ/kg			*Enthalpy,* kJ/kg		
Temp., T °C	Sat. Press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4

Superheated water

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	$P = 0.01$ MPa (45.81°C)*			
Sat.†	14.670	2437.2	2583.9	8.1488
50	14.867	2443.3	2592.0	8.1741
100	17.196	2515.5	2687.5	8.4489
150	19.513	2587.9	2783.0	8.6893
200	21.826	2661.4	2879.6	8.9049
250	24.136	2736.1	2977.5	9.1015
300	26.446	2812.3	3076.7	9.2827
400	31.063	2969.3	3280.0	9.6094

Superheated water

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	$P = 0.30$ MPa (133.52°C)			
Sat.	0.60582	2543.2	2724.9	6.9917
150	0.63402	2571.0	2761.2	7.0792
200	0.71643	2651.0	2865.9	7.3132
250	0.79645	2728.9	2967.9	7.5180
300	0.87535	2807.0	3069.6	7.7037
400	1.03155	2966.0	3275.5	8.0347
500	1.18672	3130.6	3486.6	8.3271
600	1.34139	3301.6	3704.0	8.5915

Problem 6 (15 pts).
One kmol of methane (CH_4) is burned with an unknown amount of air during a combustion process. If the combustion is complete and there are 1 kmol of free O_2 in the products, the air-fuel mass ratio is which one of the following choices?
(a) 34.6, (b) 25.7, (c) 17.2, (d) 14.3, (e) 11.9
Note: Show your work, otherwise points will not be given.

Problem 7 (15 pts).
A rigid tank is divided into two compartments by a partition. One compartment contains 3 kmol of N_2 at 400 kPa pressure and the other compartment contains 7 kmol of CO_2 at 200 kPa. Now the partition is removed, and the two gases form a homogeneous mixture at 250 kPa. The partial pressure of N_2 in the mixture is which one of the following choices?
(a) 75 kPa, (b) 90 kPa, (c) 125 kPa, (d) 175 kPa, (e) 250 kPa

Note: Show your work, otherwise points will not be given.

Problem 8 (20 pts).

A mass flow rate $\dot{m}_1$ flow of steam at the pressure P_1 and temperature T_1 should be brought to a lower temperature level T_3 by spraying in liquid water at the pressure P_2 and temperature T_2 in a steady flow. Describe the procedure (including equations and unknown properties to be looked up and calculated) to show how you can use the given conditions to further evaluate the rate of irreversibility, assuming that surroundings are at the temperature T_s.

Hint: the rate of irreversibility is the product of T_s and the entropy generation S_{gen}.