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 111 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：3102

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 111 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(0531)

考試科目（代碼）：熱力學 (3102)

 *請在【答案卷】作答

Problem 1. Water is transformed from the saturated vapor state to the saturated liquid state in a container with constant pressure at 0.1 MPa. This process occurs by a heat transfer **Δq** across the container wall to the environment at $T_0 = 20$ °C. When per kilogram of water is transformed, calculate **(20%)**:

(a) The entropy change of water. **(4 pt)**

(b) The entropy change of the environment. **(3 pt)**

(c) The entropy generation of the container. **(3 pt)**

(d) Show that the entropy generation of the container is related to the temperature difference $\Delta T = T_{sat} - T_0$ as:

$$s_{gen} = \Delta q \left[\frac{\Delta T}{(T_{sat} - \Delta T) T_{sat}}\right] \quad \textbf{(5 pt)}$$

(e) Based on the answer in (d), how can we minimize the entropy generation? Is there a limitation? **(5 pt)**

The selected properties of water are listed below.

P, MPa	T_{sat}, °C	h_f, kJ/kg	h_g, kJ/kg
0.1	99.61	417.50	2675.00

Problem 2. A heat pump is applied to warm up a room. Refrigerant R-134a enters the condenser of the heat pump at 800 kPa and 55 °C at a rate of 0.018 kg/s and leaves at 750 kPa and 26 °C. After the condenser, the refrigerant goes through the expansion valve and the evaporator, then enters the compressor at 200 kPa and -6 °C. Determine **(15%)**:

(a) The rate of heat supplied to the room. **(5 pt)**

(b) The COP of the heat pump. **(5 pt)**

(c) What is the highest COP that can be achieved if the temperature of condenser and evaporator are kept the same as the current cycle? **(5 pt)**

The selected properties of R-134a are supplied below.

P, kPa	T_{sat}, °C	h_f, kJ/kg	h_g, kJ/kg
200	-10	38.43	244.46
750	29	92.22	266.20
800	31	95.47	267.29

C_p of liquid R-134a can be assumed as constant of 1.23 kJ/kg.K, but it changes with temperature ($C_p = 0.19 + 2.56 \times 10^{-3} T - 1.30 \times 10^{-6} T^2$ kJ/kg.K) when superheated.

Problem 3. A rigid tank of volume V is to be filled with an ideal gas. Initially the gas in the tank is at P_1 and T_1. The ideal gas enters the tank at P_{in} and T_{in}. The process is adiabatic. Prove that the final temperature T_2 is:

$$T_2 = \left[\frac{(P_2 - P_1)}{(kP_2T_{in})} + \frac{P_1}{P_2}T_1\right]^{-1}$$

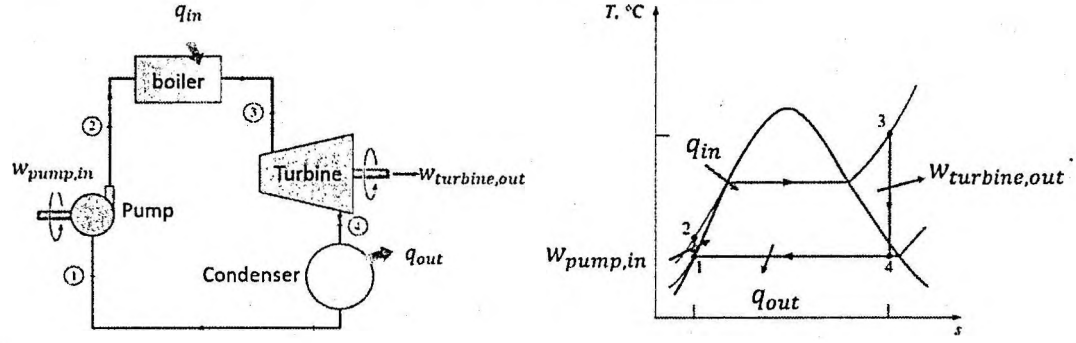
where $k = C_p/C_v$. **(15%)**

Problem 4. Normal decane ($C_{10}H_{22}$) is a fuel component in gasoline and kerosene. In a combustion lab, you are asked to program a detector that can calculate the actual equivalence ratio (ϕ) and percent theoretic air of reactants from the dry product mole fractions measured in burned gas of $C_{10}H_{22}$. The product mole fractions currently are known to be 83.61% N_2, 4.91% O_2, 10.56% CO_2 and 0.92% CO. Follow the steps below to complete the task. **(20%; 4 pts each)**

(a) Write out the mass balance for the chemical reaction.
(b) Calculate the air/fuel ratio at the stoichiometric combustion.
(c) Obtain the mass balance coefficients for C and N in the actual combustion condition.
(d) Calculate the air/fuel ratio at the actual combustion.
(e) Calculate (ϕ) and percent theoretic air of reactants.

Problem 5.

The Rankine cycle or Rankine Vapor Cycle is the process widely used by power plants such as coal-fired power plants or nuclear reactors. The pictures below show the components of a Rankine cycle (left) and its T-S diagram (right) with an ideal operation. Answer the questions below: **(15%; 5 pts each)**



(a) Sketch the deviation of actual vapor power cycle form the ideal Rankine cycle in the T-s diagram shown above.

(b) A steam power plant has a high pressure of 5 MPa and maintains 50°C in the condenser. The boiler exit temperature is 600°C. All the components are ideal except the turbine which has an actual exit state of saturated vapor at 50°C. Calculate the turbine isentropic efficiency.

(c) Following (b), you are asked to calculate the cycle efficiency with the actual turbine. Hint: the pump work can be calculated by the product of a constant specific volume and pressure difference.

Superheated Vapor Water

Temp. (°C)	v $(\frac{m^3}{kg})$	u $(\frac{kJ}{kg})$	H $(\frac{kJ}{kg})$	s $(\frac{kJ}{kg \cdot K})$
	5000 kPa (263.99°C)			
Sat.	0.03944	2597.12	2794.33	5.9733
600	0.07869	3273.01	3666.47	7.2588

Saturated Water

		Enthalpy, kJ/kg			Entropy, kJ/kg-K		
Temp. (°C)	Press. (kPa)	Sat. Liquid (h_f)	Evap. (h_{fg})	Sat. Vapor (h_g)	Sat. Liquid (s_f)	Evap. (s_{fg})	Sat. Vapor (s_g)
50	12.350	209.31	2382.75	2592.06	0.7037	7.3725	8.0762

Saturated Water

		Specific Volume, m^3/kg			Internal Energy, kJ/kg		
Temp. (°C)	Press. (kPa)	Sat. Liquid (v_f)	Evap. (v_{fg})	Sat. Vapor (v_g)	Sat. Liquid (u_f)	Evap. (u_{fg})	Sat. Vapor (u_g)
50	12.350	0.001012	12.0308	12.0318	209.30	2234.17	2443.47

Problem 6.

You are asked to evaluate the performance of a disk brake on a running car. The 10-kg iron disk brake is initially at 10°C and increased to 110°C after the brake is engaged. The specific heat of the iron is 0.45 kJ/(kg-°C). **(15%)**

1. Determine the availability of the disk during this braking action. What does the availability mean in this process? **(10 pts)**
2. Determine the energy that needs to be taken from the gas tank of the car for operating the brake. **(5 pts)**