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 110 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。

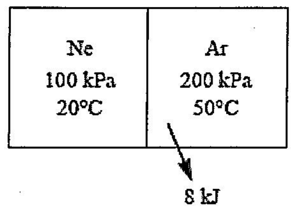
國立清華大學 110 學年度碩士班考試入學試題

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. A container has two gas species, where neon and argon are stored and separated by a partition. The given conditions are shown in the image below. The molar masses and specific heats of Ne and Ar are 20.18 kg/kmol, 39.95 kg/kmol, 0.6179 kJ/kg.°C, and 0.3122 kJ/kg.°C, respectively. **(20%; 5 pts each)**



Q1. Estimate the mole number of each gas species in the container.

Q2. If the partition in the box is removed and a heat loss takes place during the mixing process, how do you simplify the 1st law below to evaluate the mixture temperature at its equilibrium state? The first law of thermodynamics for transient processes is expressed as:

$$\dot{Q}_{\text{net,in}} - \dot{W}_{\text{net,out}} + \sum \dot{m}_i(h_i + \frac{1}{2}V_i^2 + gZ_i) - \sum \dot{m}_o(h_o + \frac{1}{2}V_o^2 + gZ_o) = \dot{m}_2(u_2 + \frac{1}{2}V_2^2 + gZ_2) - \dot{m}_1(u_1 + \frac{1}{2}V_1^2 + gZ_1)$$

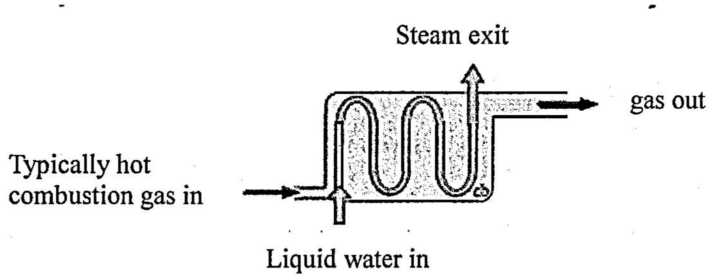
Subscripts 1 and 2 are states; subscripts i and o are inlet and outlet, respectively.

Q3. Using the simplified equation to calculate the mixture temperature at its equilibrium state.

Q4. Determine the mixture pressure at its equilibrium state.

Problem 2. Complete the questions below **(16%; 8 pts each)**:

Q1. To estimate the steady-state heat transfer rate of the liquid-to-steam in the serpentine pipe shown below, how do you simplify the 1st law of thermodynamics in **Problem 1-Q2** to do the estimation?



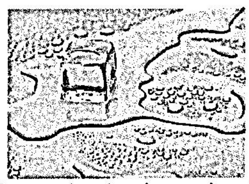
Q2. The questions below are relevant to the humidity in the air conditioning:

Q2-1. In the equation of the humidity ratio, $\omega = m_v/m_a = 0.622 * P_v/(P-P_v)$, what are P and P_v, m_v and m_a?

Q2-2. In the equation of the relative humidity, RH = P_v/P_g, what is P_g? How can P_g be obtained?

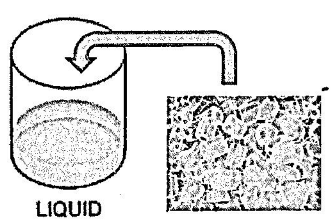
Problem 3. Assume that you are a thermal engineer working for a cryogenics company. Your project is to design the operational parameters for controlling fluid mixture (liquid and gas) temperature that is cooled by ice cubes in an insulated container. To help you to conduct this project successfully, the following questions are to be answered **(20%; 10 pts each)**:

Q1. Sketch the temperature of the ice cube versus time, as it, solely exposed to air at a room temperature, slowly turns from a solid state to a complete liquid state.

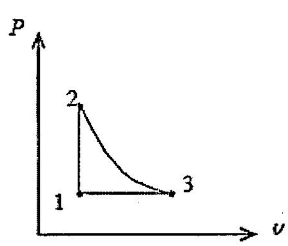


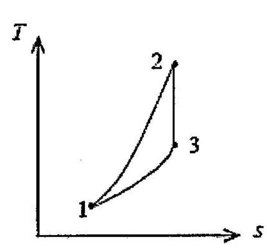
https://www.productplan.com/product-innovation-slow-melting-ice-cube/

Q2. The project is based on a problem that an insulated container is partially filled with a liquid in gas at an isothermal condition where the fluid temperature is higher than the ice temperature. Then, several ice cubes are dropped into the container (see the image below). Regarding this transient process of heat transfer, you are asked to develop a formula based on the first law of thermodynamics to predict the needed ice mass or needed ice initial temperature to achieve a targeted final temperature at its thermal equilibrium. Assuming that you know the liquid mass, liquid temperature, gas mass, gas temperature and thermodynamics properties of liquid, gas and ice. To simplify the analysis, let us assume that the mass of gas remains unchanged after the addition of ice to the container and the process of heat transfer in the container is isobaric. To derive a practical equation for the analysis described herein, how do you **make assumptions** and **simplify** the first law of the thermodynamics based on the equation shown in **Problem 1-Q2**? List the notations for each parameter and variable in the equation proposed by you.



Problem 4. The *P*-*v* and *T*-*s* diagrams below are to describe an air standard cycle.





Answer the questions below **(24%; 4 pts each)**:

Q1. Identify the processes by numbers where the heat addition, heat rejection, compression and expansion are involved in one cycle.

Q2. Using the first law of thermodynamics to derive equations for each term in Q1 in terms of the gas temperature.

Q3. Mathematically prove that the ratio of T_1 to T_3 is the reverse of the compression ratio.

Q4. In thermodynamics, we learned that the entropy balance relation can be written as:

$$\sum \frac{\dot{Q}_k}{T_k} + \sum \dot{m}_i s_i - \sum \dot{m}_e s_e + \dot{S}_{\text{gen}} = (S_2 - S_1)_{\text{cv}}/dt,$$

where any process (A to B) of the entropy change of ideal gases can be approximated with constant specific heats:

$ds = c_{\text{v,avg}} \ln(T_B/T_A) + R \ln(v_B/v_A) = c_{\text{p,avg}} \ln(T_B/T_A) - R \ln(P_B/P_A)$.

Using the equation above to mathematically derive the $T_2/T_3 = r^{(k-1)}$, and $P_2/P_3 = r^k$, where k is the ratio of c_p to c_v and r is the compression ratio.

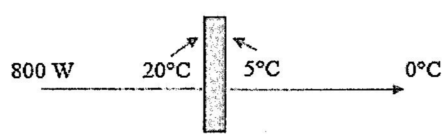
Q5. Derive the cycle thermal efficiency in terms of the gas temperature.

Q6. Derive the cycle thermal efficiency in terms of r and k.

Problem 5. Choose the correct answer in each question below and **show the equations and calculations used to get the answers (20%; 10 pts each)**:

Q1. A boiler consumes 500 kJ/s to produce heat at 1300 K in an environment at 300 K. Determine which value below is the maximum work that can be yielded by the heat in the boiler: (a) 192 kW, (b) 115 kW, (c) 385 kW, (d) 500 kW, (e) 650 kW.

Q2. Indoor heat of 800 W is leaving via a wall to outside. The inner wall surface is 20°C and outer wall surface is 5°C. The ambient temperature is 0°C outside.



Determine which value below is the rate of exergy destruction within the wall: (a) 0 W (b) 17,500 W (c) 765 W (d) 32,800 W (e) 40 W