Group A
Thermal Engineering

Entrance Examination for International Master's Program 2024

Number ____________________

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(I) Suppose a reversible closed-system cycle using an ideal gas. The gas at State 1 (temperature T_1, pressure p_1, and volume V_1) is adiabatically compressed to State 2 with a volume of V_2. From State 2 to State 3, the gas is heated at the constant volume, and the temperature reaches to T_3 at State 3. From State 3 to State 4, the gas is adiabatically expanded. Finally, from State 4 to State 1, the gas is cooled at the constant volume. The specific-heat ratio is κ independent on the temperature, and the compression ratio is given as $\varepsilon = V_1 / V_2$. (25points)

(1) Draw this cycle on a p-V diagram and a T-S diagram with the numbers of State 1, 2, 3, and 4 (p: pressure, V: volume, T: temperature, and S: entropy) on Fig. 1. It is noted that State 1 is given.

(2) Find the temperature T_2 at State 2 with T_1, κ, and ε.

(3) Find the temperature T_4 at State 4 with T_3, κ, and ε.

(4) Find the heat Q_{23} added to the gas during the process 2→3 with T_1, p_1, V_1, T_3, κ, and ε.

(5) Find the thermal efficiency η_{th} of the cycle with κ and ε.

(6) Here, introducing a parameter φ of the pressure ratio of p_3 at State 3 and p_2 at State2 ($\varphi = p_3 / p_2$), find the network L done by the gas during one cycle with p_1, V_1, κ, ε, and φ.

(7) How does the thermal efficiency η_{th} change when the parameter φ increases?

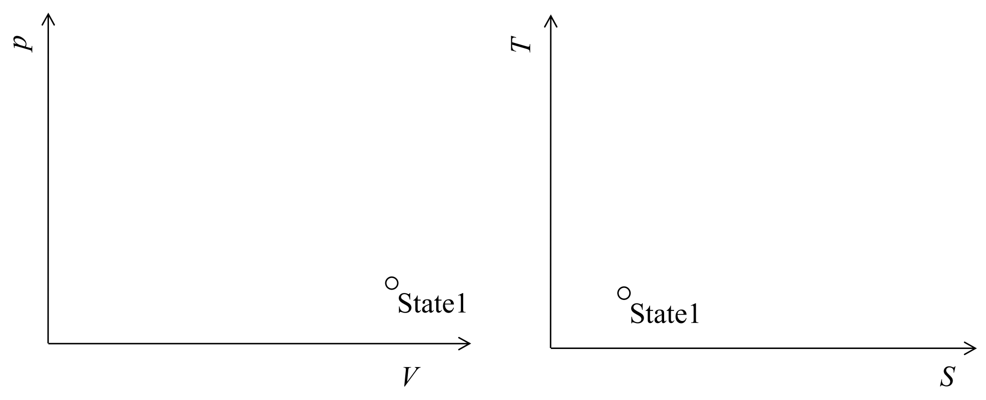

Fig. 1 p-V diagram and T-S diagram

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（Ⅱ）Solve the problem on steady-state and one-dimensional (x direction) heat transfer shown in Fig. 2.1. There are two types of flat plates A and B. The flat plate A generates heat uniformly at H (W/m^3) inside. The left side of the plate A is completely insulated, and the right side contacts with the flat plate B. The plate B does not generate heat, and the temperature on its right side is maintained at T_2. The thermal conductivities of the plates A and B are k_A and k_B (W/(m･K)) ($k_A<k_B$), and their thicknesses are L_A and L_B (m), respectively. The thermal conductivities do not depend on temperature. Set the left end of plate A to x=0. Answer the following questions using H, k_A, k_B, L_A, L_B, m, T_2, and x as necessary. (25points)

（1）Find the heat fluxes $q(x=0)$ and $q(x=L_A)$.

（2）Find the temperature T_1 at $x=L_A$.

（3）The one-dimensional steady heat conduction equation in the plate A is as follows: $k_A \frac{d^2T}{dx^2} + H = 0$. Then, find the temperature T_0 at x=0.

（4）Outline the temperature distribution in plates A and B on Fig. 2.2. Also, explain where and how you paid attention when you outline the distribution.

Next, suppose a case when the insulator loses its performance, and when m times the amount of heat generated by the entire plate A is released to the left side of the plate A($0<m<1$). Under this case, the T_0 and T_1 examined above have changed. Assuming all other conditions remain the same, answer the following questions.

（5）Answer whether the temperature at $x=L_A$ is larger or smaller than the T_1, and explain why.

（6）Find the position x that exhibits the highest temperature in plate A and explain how you can find the position.

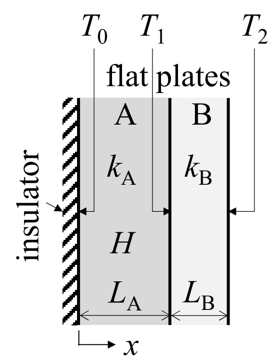

Fig. 2.1

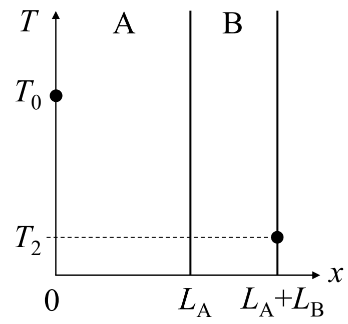

Fig. 2.2

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