2023 ENTRANCE EXAMINATION FOR INTERNATIONAL MASTER'S PROGRAM
Departments of Mechanical Engineering and Hydrogen Energy Systems

Thermal Engineering (Group A) [10:45~12:15]

Examinee's number ______________________________ Score ________

(I) Consider a reversible cycle working with an ideal gas of mass m (the gas constant is R; the temperature-independent specific heat ratio is κ). The gas at state 1 (pressure p_1, temperature T_1, and specific volume v_1) is compressed isentropically to state 2, and then expanded through a constant-pressure heat addition to state 3. The gas is further expanded isentropically from state 3 to state 4, and then finally returned to state 1 through a constant-volume heat rejection. Noting that the subscripts 1-4 denote each state, answer the following questions. Take $r_0 = v_1/v_2$ and $r_C = v_3/v_2$ (25 points).

(1) Illustrate the cycle in a p–v diagram and a T–s (specific entropy) diagram clearly indicating states 1, 2, 3, and 4.

(2) Express T_2, T_3, and T_4 in terms of T_1, κ, r_0, and r_C. Note that you may not need all four parameters for each expression.

(3) Express the heat added per unit mass to the gas q_{in} and the heat rejected per unit mass by the gas q_{out} in terms of R, T_1, κ, r_0, and r_C. Note that you may not need all five parameters for each expression.

(4) Derive an expression for the thermal efficiency η of this cycle in terms of r_0, r_C, and κ.

(5) Derive expressions for the change in specific entropy for the constant-pressure process 2→3 and the constant-volume process 4→1 in terms of R, κ, and r_C.

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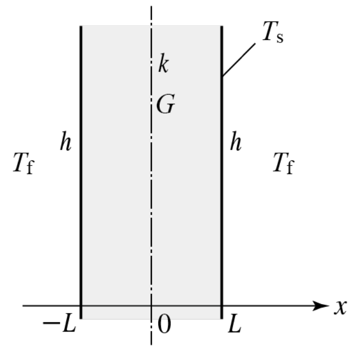

(II) An infinite flat plate (thickness $2L$ and thermal conductivity k) in a fluid uniformly generates a volumetric heat of G per unit volume and time. Assuming the a one-dimensional steady-state heat conduction along x direction, answer the following questions (25 points).

(1) By considering the heat balance within a control volume of thickness Δx in the flat plate, derive the following one-dimensional heat conduction equation of the plate: $\frac{d^2T}{dx^2} = -\frac{G}{k}$

(2) Derive the temperature distribution $T(x)$ in the flat plate when the surface temperature of the plate is T_s.

(3) Derive an expression for the surface temperature T_s when the bulk temperature of the fluid is T_f and the heat transfer coefficient between the plate and fluid is h.

(4) Find the minimum heat transfer coefficient h_{min} in order to keep the maximum temperature in the plate at or below T_{max}.