(I)A reversible cycle is considered as shown in Fig. 1. The working fluid of mass m is an ideal gas whose specific heat is independent of temperature. From State 1 to State 2, the gas is compressed isothermally at a temperature T_L. From State 2 to State 3, the gas is heated at a constant pressure p_H. From State 3 to State 4, the gas expands isothermally at a temperature T_H. From State 4 to State 1, the gas is cooled at a constant pressure p_L. The gas constant and the specific-heat ratio of the gas are R and κ, respectively. Answer the following questions using the above given symbols of physical quantities. (25points)

(1) Draw this cycle on a T–S diagram with the numbers of States 1, 2, 3 and 4. (T: temperature, S: entropy)

(2) Find the heat Q_{12} rejected from the gas during the process 1→2.

(3) Find the heat Q_{23} added to the gas during the process 2→3.

(4) Prove the relation $Q_{23}= Q_{41}$. Here, Q_{41} is the heat rejected from the gas during the process 4→1.

(5) Find the net work W done by the gas during one cycle.

(6) A modification embedding a regenerator, where the rejected heat Q_{41} is stored in the regenerator and then transferred back to the gas as Q_{23}, is proposed. When this modification is applied to the cycle, prove that the thermal efficiency of this modified cycle is the same as that of the Carnot cycle.

(7) Although the modified cycle has not been practically realized, we can approximately realize the cycle with some improvements on the Brayton cycle (an ideal cycle for gas-turbine engine). How do you improve the Brayton cycle?

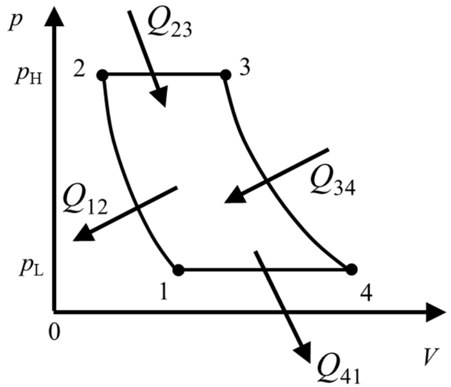

Fig. 1 $p-V$ diagram

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(Ⅱ) Both sides of the flat plate having thickness $2L$ (m), thermal conductivity k (W/(m・K)), density ρ (kg/m^3), specific heat c (J/(kg・K)), and uniform volumetric heat generation of H (W/m^3) are exposed to a fluid of temperature T_∞ (K). Under steady state conditions, the temperature distribution inside the flat plate is $T(x) = \alpha + \beta x + \gamma x^2$ (K), where $\alpha > 0$, $\beta < 0$, and $\gamma < 0$.
Answer the following questions using $L, k, \rho, c, T_\infty, x, \alpha, \beta,$ and γ as necessary. (25 points)

(1) Find the heat flux distribution $q(x)$ in the flat plate. And find the position x where the temperature gradient becomes zero.
(2) Find the heat fluxes $q(x)$ at $x = L$ and $x = -L$.
(3) Find the volumetric heat generation of H (W/m^3).
(4) Find the heat transfer coefficients h at $x = L$ and $x = -L$.
(5) Find the temperature of the flat plate after enough time has elapsed after the heat generation inside the flat plate has stopped. How much heat per unit area (J/m^2) must be removed after the heating is stopped before reaching the steady state?

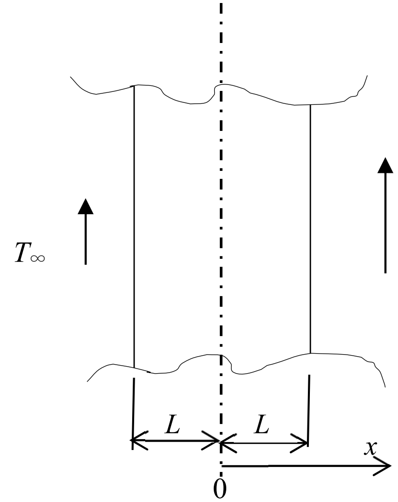

Fig.2

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