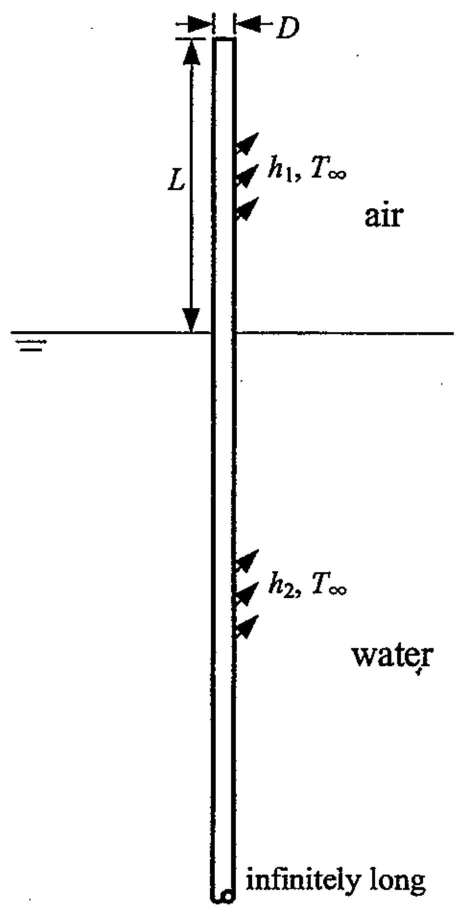
※ 注意：請於試卷上「非選擇題作答區」內依序作答，並應註明作答之部份及其題號。

Problem 1.

Uniform volumetric heating rate $\dot{q}$ is generated electrically in a vertical rod of diameter D as shown in the figure below. The upper part, of length L, of this rod is in still ambient air at temperature T_∞. The lower part is very long and immersed in still water at the same temperature. The heat transfer coefficients from the upper and lower parts are h_1 and h_2, respectively. Derive the temperature distribution in the rod. The rod diameter $D << L$, while the upper exposed tip of the rod is considered adiabatic. (20%)



Problem 2.

A company claims that they have a black-box device which operates at steady state, and has two inlet streams and one outlet stream. Inlet 1 allows air to enter at a pressure of 200 kPa, temperature of -50°C, and mass flow rate of 30 kg/min. Inlet 2 allows air in at 100 kPa, temperature of 150°C, and mass flow rate of 20 kg/min. The outlet is at a pressure of 190 kPa. They further claims that this device is insulated and requires no work input. In

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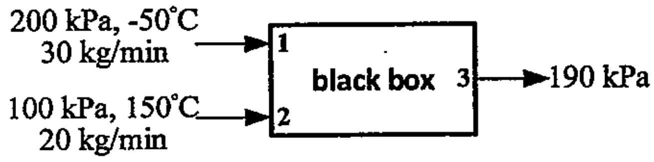
your analysis, treat the air as an ideal gas with constant specific heats. Also R = 0.287 kJ/kg·°C and Cp = 1 kJ/kg·°C.

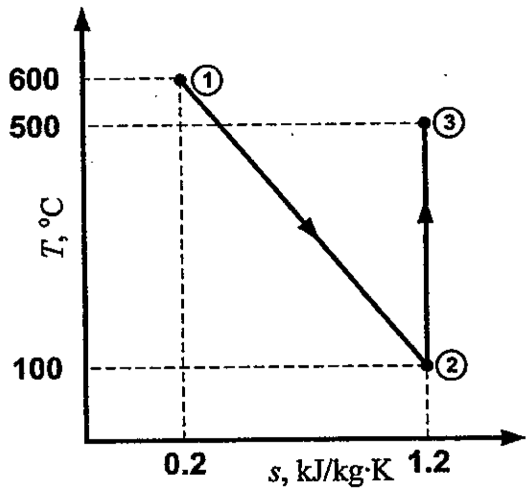
(a) Determine whether such a device is possible. (10%)
(b) If the device is possible, determine the maximum work that you can extract from the device. If the device is not possible, determine what is the minimum amount of work that must be done on the system to make the device possible. Assume that the outlet pressure remains unchanged. (10%)



Problem 3.

A closed system undergoes processes 1-2 and 2-3, which are internally reversible and shown in the figure below.

(a) For processes 1-2-3, determine whether the system absorbs or rejects heat, and the associated heat transfer, in kJ/kg. (5%)
(b) If the system contains an ideal gas of C_P = 1.5 kJ/kg·K and R = 0.5 kJ/kg·K, does the system do any work or receive any work during processes 1-2-3? Determine the associated work, in kJ/kg. (5%)



Problem 4.

Please derive the Mayer relation (15%), i.e.,

$$c_p - c_v = \frac{vT\beta^2}{\alpha}, \tag{4.1}$$

where c_p is the constant-pressure specific heat, c_v is the constant-volume specific heat, v is the specific volume, T is the (absolute) temperature,

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P, \tag{4.2}$$

is the volume expansivity, and

$$\alpha = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T, \tag{4.3}$$

is the isothermal compressibility. Please also show that for ideal gases, Eq. (4.1) reduces into

$$c_p - c_v = R, \tag{4.4}$$

with R being the gas constant (5%).

Problem 5.

Shown in the figure below is a solid wall of thickness L, cross sectional area A_c, and thermal conductivity k separating two fluid medium. The fluid medium on the left hand side of the wall is called Fluid 1 and is at uniform temperature T_1 whereas the fluid medium on the right hand side of the wall is termed Fluid 2 and is at uniform temperature T_2. We assume Fluid 1 is at a higher temperature than Fluid 2, i.e., $T_1 > T_2$, such that a steady rate of heat transfer $\dot{Q}$ (with units of W) is being transported from Fluid 1, through the solid wall, and then into Fluid 2. Based on the coordinate system shown in the figure and neglecting boundary layer effects throughout the whole system under this steady state, the boundary conditions on the solid wall temperature distribution are given as $T(x=0)=T_1$ and $T(x=L)=T_2$. Please answer the following:

I. (6%) Please calculate the entropy generation rate, $\dot{S}_{gen}$, within the solid wall.

II. (6%) With the temperature of the environment far away from the fluid-wall system being T_0, please calculate the rate of availability (or exergy) destroyed, $\dot{X}_{des}$, within the solid wall.

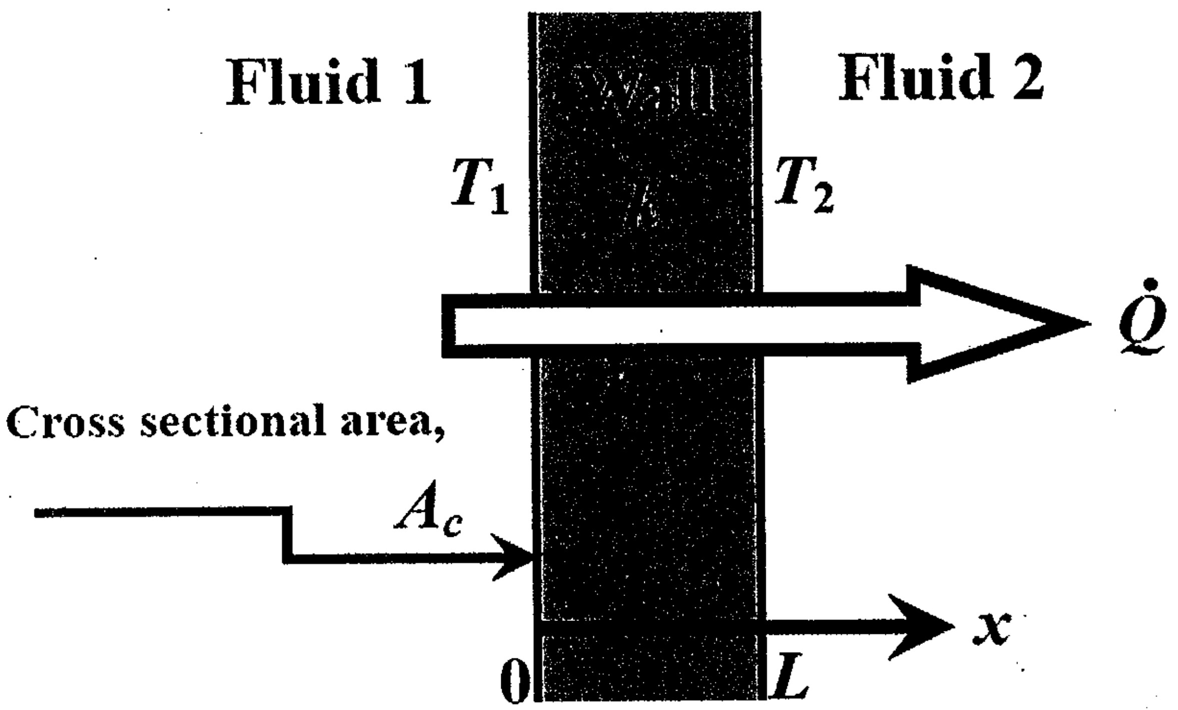
III. (6%) Starting from the *conduction equation*, please solve for the steady temperature distribution within the wall when subjected to the boundary conditions given above.

IV. (6%) For heat conduction in solids, the entropy generation rate *per unit volume*, s'', can be expressed in terms of the temperature, T, and the heat flux, $\bar{q}$ (with units of W/m^2), i.e.,

$$s'' = -\frac{1}{T^2}\left(\bar{q}\cdot\nabla T\right). \tag{5.1}$$

Using Eq. (5.1), please calculate the entropy generation rate of the *whole* solid wall. How does the answer found in (IV) compare with that obtained in (I)?

V. (6%) Where does the irreversibility (causing entropy generation) come from throughout the system?



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