Thermal Engineering (Group A) [11:00~12:30]

(I) Consider an ideal cycle working with an ideal gas (the gas constant R, the temperature-independent specific heat ratio κ). The gas at state 1 (pressure p_1, temperature T_1, and specific volume v_1) is pressurized using a compressor by an isentropic process to state 2, and heated to state 3 in a heater at constant pressure. Then the gas is introduced in a turbine and isentropically expands to state 4, and then finally returns to state 1 by cooling at constant pressure. Noting that the subscripts 1-4 denote each state, answer the following questions.
Use the pressure ratio defined by $\gamma = p_2/p_1$ if required in the questions (25 points).

(1) Illustrate the p–v diagram and T–s (specific entropy) diagram of this cycle clearly indicating states 1, 2, 3 and 4.
(2) Express temperature T_2 in terms of T_1, γ and κ. Similarly, express T_4 in terms of T_3, γ and κ.
(3) Determine the work done by a unit mass of gas in the turbine and express it in terms of R, T_3, γ and κ.
(4) Determine the work done by the compressor on a unit mass of gas and express it in terms of R, T_1, γ and κ.
(5) Determine the thermal efficiency η_{th} of this cycle and express it in terms of γ and κ.
(6) From the following applications choose two that most commonly use a system based on this cycle:
(a) Automobile, (b) Aircraft, (c) Locomotive, (d) Ship, (e) Electric power generation, (f) Air conditioning

(II) A rectangular block (thickness d, cross-sectional area A, and thermal conductivity k) embedded in an adiabatic material is heated from the bottom using a heater and cooled at the top surface by water flowing at the temperature T_{in} in a channel (mass flow rate $\dot{m}$ and specific heat c). To estimate the heat transfer coefficient from the surface to water, temperatures are measured at the middle of the block using thermocouples at heights $z = \frac{d}{2}$ and $z = \frac{3}{4}d$ from the bottom, which are denoted by T_1 and T_2, respectively. Answer the following questions (25 points).

(1) Determine the temperature T_3 at the top of the block ($z = d$).
(2) Determine the rate of heat generation $\dot{Q}$ in the heater.
(3) Determine the bulk mean temperature of the cooling water at the outlet, T_{out}.
(4) Determine the local heat transfer coefficient h at the middle of the block.
(5) The thermocouple at $z = \frac{d}{2}$ is actually misaligned slightly to the heater side. Does this make the local heat transfer coefficient h estimated in (4) larger or smaller than the actual value? Answer with the reason.