Thermodynamics

Caution: Students please read before starting

(1) You should be provided with a set of thermodynamics properties tables for use during this exam.

(2) The exam consists of three (3) problems on three (3) separate pages. Check NOW to verify that your exam is complete.

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If you are missing the properties tables or any of the three (3) exam pages stop work NOW and advise your proctor immediately.

Problem 1

A rigid, stainless steel cylinder contains refrigerant R-134a with a volume of 130 mL (i.e., $1.3\times10^{-4}\ \mathrm{m}^3$). The mass of the cylinder itself (stainless steel) is m_S = 0.82 kg, and the mass of the refrigerant is m_R = 0.03 kg. Initially, the cylinder and the R-134a are at 24 °C.

The cylinder containing R-134a is suddenly immersed into a container of hot liquid water with a mass m_W = 0.60 kg. An equilibrium temperature of 44 °C between the water bath, the cylinder, and the R-134a is quickly reached. The specific heats of the stainless steel and water are c_S = 0.47 kJ/kg·K and c_W = 4.18 kJ/kg·K, respectively. Neglect the temperature dependence of the specific heat of the stainless steel or water.

Assume that the heat or mass transfer between the water and the environment is negligible. Also, neglect the mass and heat capacity of the water container.

Find the initial temperature of the water. List all assumptions.

Problem 2

Consider a steady state closed system known as a "combined heat and power" (CHP) system. The system receives high temperature heat at the rate of 1000 kW at an effective temperature of 500 °C and rejects industrial process heat (IPH) at 150°C and also produces shaft power. The ambient temperature is 300 K. It is known that the system has internal "irreversibility" (also known as exergy destruction rate = $T_0\,\dot{S}_{\mathrm{gen}}$) equal to 10% of the shaft power. Draw a sketch of the system for thermodynamic analysis and answer the following questions. Put sketch here:

(a) Explain very briefly in the space below the general development or background of the thermodynamic theory that results in the formula, $T_0\,\dot{S}_{\mathrm{gen}}$, for the "irreversibility" and explain the significance of this term in the analysis of a system such as this one:

(b) For the specified irreversibility equal to 10% of the shaft power, what is the shaft power output and IPH output? Power = ______________ kW and IPH = ______________ kW

Show your work on an attached worksheet.

(c) For the system of part (b), define an exergy or "combined laws" efficiency as the ratio of all the exergy outputs to all the exergy input, and compute the exergy efficiency for the conditions of part (b), efficiency = ____________

Show your mathematical definition and your work on an attached worksheet.

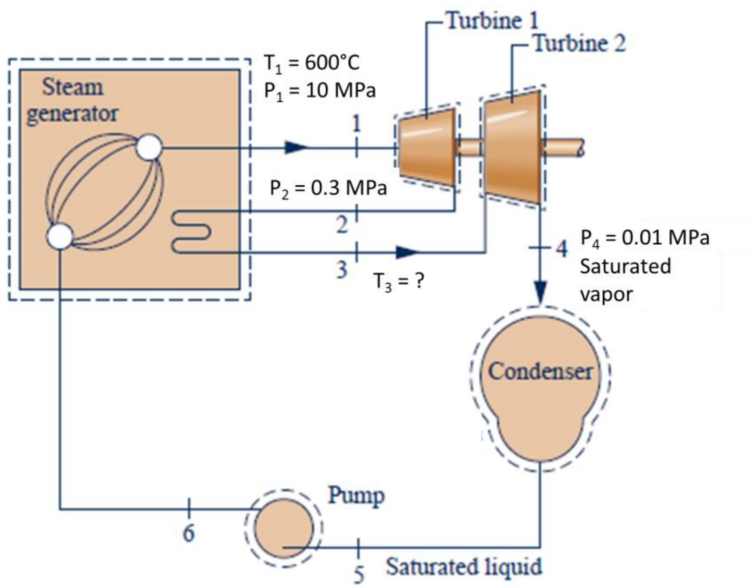
(d) For an improved version of this system, the shaft power is claimed to be 425 kW for the same input heat (1000 kW) and the same specified temperatures. Determine if this performance is reasonable, and explain and justify your response below or on attached worksheet:

Is performance reasonable? ☐yes or ☐no

Explain below or on attached sheet and justify your assessment with quantitative analysis:

Problem 3

Steam is the working fluid in an ideal Rankine cycle with superheat and reheat. Steam enters the first-stage turbine at 10 MPa, 600 °C, and expands to 0.3 MPa. It is then reheated to a certain temperature before entering the second-stage turbine, where it expands to the condenser pressure of 0.01 MPa. Saturated vapor enters the condenser and saturated liquid exits the condenser.



Questions:

(a) Determine the reheat temperature, in °C (3 pts).

(b) Determine the thermal efficiency (4 pts).

(c) Reconsider the reheat cycle, but include in the analysis that each turbine stage has the same isentropic efficiency. If η_t = 85%, determine the thermal efficiency (3 pts).