THERMODYNAMICS QUALIFYING EXAM

January 2006

OPEN BOOK (only one book allowed) & CLOSED NOTES

Answer all four questions

All questions have equal weight

TIME: 3.0 hrs

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- Take any required property from your book, approximate values if necessary.
- If you make any assumption to reach a solution state it clearly
**Question # 1**

Consider the Rankine cycle below with steam flow rate of 5 kg/s. The steam receives heat from the combustion gases in the furnace of the generator; assume the combustion gases change temperature from 2000 K to 425 K in flowing through the steam generator. The cooling water enters the condenser 20°C and leaves at 40°C. Assume the flow in the pump and the turbine is adiabatic and internally reversible. Also assume the combustion gas has the properties of air. If \( T_p \) is 20°C, determine the cycle irreversibility, \( I \). The irreversibility, \( I \) is given by:

\[
I = T_0 \left[ \sum_i (m_i s_i)_{out} - \sum_j (m_j s_j)_{in} + \sum \frac{Q_i}{T_i} \right]
\]
Question # 2
A compressor operates at steady state with Refrigerant 22 as the working fluid. The refrigerant enters at 5 bar, 10°C, with a volumetric flow rate of 0.8 m³/min. The diameters of the inlet and exit pipes are 4 and 2 cm, respectively. At the exit, the pressure is 14 bar and the temperature is 90°C. If the magnitude of the heat transfer rate from the compressor to its surroundings is 5% of the compressor power input, determine the power input.
Question #3

An insulated, rigid tank is divided into two compartments by a frictionless, thermally conducting piston. One compartment initially contains 1 m³ of helium gas (He) at 2 bar, 300 K and the other compartment contains 1 m³ of helium gas (He) at 1 bar, 400 K. The piston is released and equilibrium is attained, with the piston experiencing no change of state. Employing the ideal gas model for the gas, determine the final temperature, the final pressure, and the amount of entropy produced.
Question # 4

i) An ideal cycle consists of 3kg of air undergoing a cyclic process:
   • From 1 → 2 polytropic compression, where \( p_1 = 150 \text{kPa}, \ T_1 = 360 \text{K}, \)
   \( p_2 = 750 \text{kPa} \) and \( n = 1.2 \)
   • From 2 → 3 cooling @ \( \Delta p = 0 \)
   • From 3 → 1 heating @ \( \Delta T = 0 \)

Determine:
   a) The temperature, pressure and volume at each state
   b) The heat and work transfers
   c) Sketch the T-S and P-V diagrams for the cycle.

ii) A closed system containing an ideal gas undergoes a process where the temperature of the gas changes from an initial to a final value. Prove that the change in entropy will be greater if the process was a constant pressure instead of a constant volume.

iii) A liquid of mass \( m \) at a temperature of \( T_1 \) is mixed with another identical liquid of equal mass \( m \) and at a temperature of \( T_2 \). Since the liquids are identical, they have the same specific heat \( (C_p) \). The mixing occurs in a container which is completely insulated on the outside, show that the net entropy change of the mixing can be expressed by:

\[
\Delta S_{\text{net}} = 2C_p m \ln \left( \frac{(T_1 + T_2)/2}{\sqrt{T_1 T_2}} \right)
\]