Qualifying Examination 2023

Thermodynamics

Logistics Notes:

- Duration: 3 hours.
- Open book (the textbook provided during the exam).
- Calculator is allowed.
- Laptops, cell phones, and similar electronic devices are **not allowed**.
- State your assumptions for each problem.

Problems:

Problem A (45 points) Air contained within a piston-cylinder assembly undergoes a thermodynamic cycle consisting of four processes in series:
Process 1-2: isothermal expansion at 600 K from $p_1 = 0.5$ MPa to $p_2 = 0.4$ MPa,
Process 2-3: polytropic expansion with $n = k$, where k is the specific heat ratio, to state 3 with pressure $p_3 = 0.3$ MPa,
Process 3-4: isobaric compression to $V_4 = V_1$,
Process 4-1: isochoric process from state 4 to state 1 where energy is added to the air by heating. Changes in potential and kinetic energies are negligible. Air can be modeled as an ideal gas and its specific heat ratio can be assumed constant, equal to 1.4. All processes are reversible.

Sketch the cycle on a p-V diagram and determine:

1. work and heat transfer per unit mass during each process of the cycle,

2. the cycle type (power, refrigeration, or heat pump) and its efficiency.

Problem B (35 points) Water at 100 bar, 600°C enters a turbine operating at steady state and exits as saturated vapor at 1 bar. The mass flow rate is 10 kg/s. The turbine is well-insulated and kinetic and potential energy effects are negligible. **Determine:**

1. the power developed by the turbine,
1. the isentropic turbine efficiency,
2. the rate of entropy production within the turbine.

Comment on the turbine possibility.

Problem C (20 points) During an experiment, data of pressure, temperature, and velocity were recorded for air flowing at steady state through a horizontal, insulated round duct at two locations: A and B. At location A, measurements were 0.95 bar, 67°C, and 75 m/s, respectively, and at location B, they were 0.8 bar, 22°C, and 310 m/s. Using provided data, determine the air flow direction in this experiment. Air can be modeled as an ideal gas.

Solve problems in the order of your preferences. Add pages as necessary indicating a problem to which the added pages belong to.

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