SCHOOL OF ENGINEERING
MECHANICAL ENGINEERING

EPFL

Thermodynamics and energetics I: Exercise 5

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1. Consider an ideal Stirling cycle in a closed cylinder-piston-system using 1.5 kg of N_2, which can be considered ideal gas. The gas runs through the following processes:

   - 1-2: Isothermal expansion at 2000 K and $p_1 = 20$ bar.
   - 2-3: Isochoric cooling.
   - 3-4: Isothermal compression at 300 K and $p_3 = 1$ bar.
   - 4-1: Isochoric heating with $|Q_{23}| = |Q_{41}|$. The heat extracted in process 2-3 is stored in a temporary heat storage and entirely put back into the system in process 4-1.

   (a) Sketch the pv and Tv diagrams.

   (b) Calculate the temperature and pressure in each state.

   (c) Calculate $|Q_{23}| = |Q_{41}|$; for this question approximate N_2 as perfect gas with specific heat ratio of 1.333.

   (d) Calculate the net work delivered by the cycle.

2. The inlet of a jet engine shapes a diffuser which reduces air relative velocity with respect to the engine to zero before it enters the compressor. Jet inlet relative velocity is 1000 km/h, local atmospheric pressure is 0.6 bar and temperature is 8 °C. Calculate the temperature of the air at the outlet of the diffuser assuming perfect gas with $c_p = 1005$ J/kg/K and neglecting potential energy variation. Consider steady state and adiabatic operation.

3. We consider a balloon filled with helium (perfect gas: $c_p = 5.1926$ kJ/(kg · K)). The balloon has a volume of 65 m^3 and is in equilibrium with the environment ($p = 100$ kPa, $T = 22$ °C). The balloon is connected to a big helium tank with a pressure of 150 kPa and a temperature of 25 °C. The valve is opened and the helium flows into the balloon until a new equilibrium is obtained. The balloon is made of a material that leads to a linear increase in volume with pressure (assume that pressure is zero when volume is zero). Determine the temperature of the new mechanical equilibrium state assuming that the process is adiabatic.