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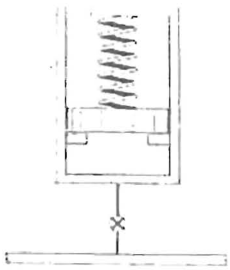
1. An insulated cylinder has a frictionless piston held against stops by a linear spring with spring constant 100 kN/m. The cylinder pressure to float the piston is 200 kPa. The piston cross-sectional area is 0.1 m^2. The cylinder initial volume of 0.01 m^3 contains air at ambient conditions, 100 kPa and 20 °C. A valve connects to a line flowing air at 300 kPa, 40 °C. The valve is now opened, allowing air to flow in until the cylinder final volume is twice the initial volume. The valve is then closed and the process ends. Assume air is an ideal gas, with constant specific heat, C_p = 1.004 kJ/kg-K, C_v = 0.717 kJ/kg-K, and R = 0.287 kJ/kg-K. (30%)

   (a) Find the final pressure, final temperature, and the work during the process.

   (b) Verify that this process can take place in accordance with the principle of the increase of entropy.

   (c) Plot the process in a P-V diagram.



2. A cylinder/piston initial volume of 0.2 m^3 contains air at ambient conditions, 100 kPa and 20 °C. The air is compressed to 600 kPa in a reversible polytropic process with exponent, n = 1.2 and then expanded back to 100 kPa through either a reversible adiabatic process or a reversible isothermal process. Which choice will result in the positive net work by the system? Demonstrate your answer by evaluating the net work for each case. Also, plot the processes on the same P-V and T-s diagrams. Assume air is an ideal gas, with constant specific heat, C_p = 1.004 kJ/kg-K, C_v = 0.717 kJ/kg-K, and R = 0.287 kJ/kg-K. (20%)

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3. Consider an ideal air-standard Brayton cycle which delivers a power output of 100 MW to an electric generator. The minimum temperature in the cycle is 300 K and the maximum temperature is 1600 K. The minimum pressure in the cycle is 100 kPa and the compressor pressure ratio is 14 to 1. Assume constant specific heats for the air, $C_v = 0.717\ \text{kJ/kg-K}$ and $C_p = 1.004\ \text{kJ/kg-K}$. Determine the compressor work, the turbine work, and the thermal efficiency of the cycle.

(20 %)

4. In the *P*-*v* plane of a particular substance, two states, *A* and *D*, are defined by

$P_A = 10^5\ \text{Pa}$, $v_A = 2\times10^{-2}\ \text{m}^3/\text{mole}$,

$P_D = 10^4\ \text{Pa}$, $v_A = 10^{-1}\ \text{m}^3/\text{mole}$.

Besides, it is also ascertained that $T_A = 350.9\ \text{K}$. If 1 mole of this substance is initially in the state *A*, and if a thermal reservoir at temperature $T = 150\ \text{K}$ is available, find the maximum work that can be delivered in a reversible process $A \rightarrow D$. The following data are available. The isentropic processes of the system are of the form $Pv^2 = \text{constant}$. Measurements of c_p and α (coefficient of thermal expansion) are known only at the pressure of $10^5\ \text{Pa}$, $c_p = Bv^{2/3}$ with $B = 464.2\ \text{J/m}^2\cdot\text{K} = 10^{8/3}\ \text{J/m}^2\cdot\text{K}$, $\alpha = 3/T$, and no measurements of κ_T (isothermal compressibility) are available. (30 %)