Problems Chapter 8

Notes: 1 bar = 100 kPa, use constant specific heats unless otherwise directed.

Availability for closed systems

8-1 A tank with a volume of 0.30 m^3 contains air at: (a) 6 bars and 300 K, and (b) 6 bars and 600 K. The surrounding atmosphere is at 0.95 bar and 500 K. Determine the availability of the air in kilojoules.

8-2 The air in Prob. 8-1 undergoes isentropic expansion until its volume is (1) doubled, and (2) tripled. Determine the change in the closed-system availability for the process, in kilojoules, for an initial state of (a) 6 bars and 300 K, and (b) 6 bars and 600 K.

8-3 Determine the availability associated with 50 kg of water at 0 °C and 0.95 bar if the surrounding atmosphere is at 0.95 bar and 20 °C, in kilojoules.

8-4 Fifty kilograms of water at 0 °C and 0.95 bar are allowed to mix in a closed system with 30 kg of water at 80 °C and 0.95 bar. Determine the optimum useful work associated with the change of slate of (a) the 50 kg of water, and (b) the 30 kg of water, (c) Find the change in availability for the overall adiabatic process, in kilojoules. T_0 = 20 °C and P_0 = 1 bar.

8-5 Determine the availability of steam in a closed system at 80 bars and 400 °C, in kJ/kg. The environment is at 1 bar and 25 °C.

8-6 The steam in Prob. 8-5 is cooled in a rigid tank until the pressure drops to 40 bars. Determine the optimum useful work associated with the change in state of the fluid, in kJ/kg.

8-7 Air initially at 1 bar and 27 °C is contained in a well-insulated tank. An impeller inside the tank is turned by an external mechanism until the pressure is 1.2 bars. Determine (a) the actual work required, and (b) the optimum useful work associated with the change in state, both in kJ/kg. Let T_0 = 27 °C and P_0 = 1 bar.

8-8 A piston-cylinder device contains 0.40 kg of air at 0.10 MPa and 27 °C. Determine the minimum work input, in kilojoules, required to compress the air to 0.40 MPa and 127 °C. T_0 = 20°C and P_0 = 0.10 MPa.

8-9 Refrigerant 12 is compressed from a saturated vapor at -10°C to a final pressure of 8 bars. The process is adiabatic and the compressor efficiency is 78 percent. Determine (a) the actual work required, in kJ/kg, and (b) the actual outlet temperature, in degrees Celsius, (c) Find the minimum work required, in kJ/kg, for the actual final state found in part b. The process occurs in a piston-cylinder device. T_0 = 20 °C and P_0 = 1 bar.

8-10 A storage battery is capable of delivering 1 kWh of energy. Determine the volume of air stored in a tank at 27 °C and (a) 15 bars, and (b) 30 bars, that is needed to theoretically have the same work capability. The state of the environment is 27 °C and 1 bar.

Available energy for closed systems

8-16 A constant-volume tank contains saturated water vapor at 90 °C. Heat is added to the water until the pressure in the tank reaches (a) 1.5 bars, and (b) 1 bar. For a sink temperature of 10 °C, compute how much of the heat added is available energy.

8-17 A kilogram of air at 1.8 bars is cooled at constant volume from 450 to 300 K. All the heat which leaves the system appears in the surroundings at (a) 12 °C, and (b) 21 °C. Determine how much of the heat removed is available energy, in kilojoules. Draw a *Ts* diagram for the process, and label the areas which represent available and unavailable energy.

8-18 Ten kilograms of air at 1 bar and 350 K are in a closed, rigid tank. Heat is transferred to the air from a thermal-energy reservoir that has a constant temperature of 500 °K. The ambient temperature is 300 °K. (a) How much heat, in kilojoules, can be transferred to the air from the energy source? (b) How much of the heat transferred to the air is available energy?

8-19 Air at 1 bar is cooled at constant pressure from 440 to 300 °K, with all the heat given up by the system appearing in the environment, which has a temperature of 290 °K. Determine how much of the heat removed is available energy for the closed system, in kJ/kg.

8-20 Steam at 3 bars and (a) 240 C, and (6) 280 C is allowed to cool at constant pressure in a closed system until it reaches thermal equilibrium with the surroundings at 20 °C. Compute the loss in available energy due to the irreversible heat transfer, in kJ/kg.

8-21 Heat for a heat engine is available at a constant temperature of 1427 C, but actually is transferred to the working medium of the engine at 500 °K. The lowest available environmental temperature is 300 K. What fraction of the heat supplied becomes unavailable because the heat transferred is received by the working fluid at 500 °K rather than 1427 C?

8-22 A tank with a volume of 10 ft^3 contains air at (a) 100 psia and 70 F, and (b) 100 psia and 300 F. The surrounding atmosphere is at 14.5 psia and 70 F. Determine the availability of the air, in Btu.

8-23 Determine the availability associated with 50 Ib_m of (a) ice, and (b) water at 32 F and 1 atm if the surrounding atmosphere is at 1 atm and 60 F, in Btu.

8-24 Determine the availability of steam in a closed system at 1000 psia and 800 F, in Btu/lb_m. The environment is at 14.7 psia and 70 F.

8-25 A piston-cylinder device contains 0.40 lb_m of air at 15 psia and 70 F. Determine the minimum work input, in Btu, required to compress the air to 60 psia and 250 F. T_0 = 70 F and P_0 = 15 psia.

8-26 A constant-volume tank contains dry, saturated water vapor at 200 F. Heat is added to the water until the pressure in the tank reaches 20 psia. For a sink temperature of 50 F, compute how much of the heat added is available energy.

Availability in open systems

8-27 Air enters a steady-flow turbine at 3 bars and 480 °K and exhausts at 1 bar and 380 °K. The process is adiabatic and the surroundings are at 1 bar and 20 C. Compute (a) the actual work output, and (b) the optimum shaft work output, in kJ/kg.

8-28 Steam enters a turbine at 40 bars and 400 C and expands to 1 bar and 100 C, in a steady flow, adiabatic process. The ambient conditions are 1 bar and 27 C. Disregard changes in kinetic and potential energy. Find (a) the actual work delivered, and (b) the optimum shaft work, in kJ/kg.

8-29 Air enters a compressor in steady flow at 1.4 bars, 17 C, and 70 m/s. It leaves the adiabatic device at 4.2 bars, 147 C, and 110 m/s. Determine (a) the actual work input, and (b) the optimum work required, in kJ/kg, if T_0 = 7 C and P_0 = 1 bar.

8-30 Refrigerant 12 is compressed in steady flow from a saturated vapor at -10 C to a final state of 8 bars and 50 C. For the adiabatic process determine (a) the actual work required, and (b) the minimum work required, in kJ/kg, if T_0 = 20 C and P_0 = 1 bar.

8-31 Steam enters a turbine at 100 bars and 560 C at a rate of 50,000 kg/h. Partway through the turbine, 25 percent of the flow is bled off at 20 bars and 440 C. The rest of the steam leaves the turbine at 0.10 bar as a saturated vapor. Determine (a) the availability at the three states of interest, in kJ/kg, (b) the maximum power output possible, in kilowatts, and (c) the actual power output, in kilowatts, if the flow is adiabatic. The environment is at 1 bar and 20 C.

8-32 A hydrocarbon oil is to be cooled in a heat exchanger from 440 to 320 K by exchanging heat with water which enters the exchanger at 20 C at a rate of 3000 kg/h. The oil flows at a rate of 750 kg/h, and has an average specific heat of 2.30 kJ/kgK. Compute the change in flow availability, in kJ/h, for (a) the hydrocarbon oil stream, and (b) the water stream, (c) Find the loss in availability, in kJ/h, for the overall process if T_0 = 17 C.

8-33 Refrigerant 134a with a mass flow rate of 5 kg/min enters a condenser at 14 bars, 80 C, and leaves at a state of 52 C, 13.8 bars. Determine the loss in availability, in kJ/min, if the coolant in the condenser is (a) water which enters at 12 C and 7 bars and leaves at 24 C and 7 bars, and (b) air which experiences a 9 C temperature rise from 18 C at a constant pressure of 1.1 bars. T_0 = 15°C.

8-34 Air enters a steady-flow turbine at 45 psia and 400 F and exhausts at 15 psia and 200 F. The process is adiabatic and the surroundings are at 14.7 psia and 70 F. Compute (a) the actual work output, and (b) the optimum shaft work output, in Btu/lb.

8-35 Steam enters a turbine at 400 psia and 700 F and expands to 14.7 psia and 250 F, in a steady-flow, adiabatic process. The ambient conditions are 14.7 psia and 80 F. Disregard changes in kinetic and potential energy. Find (a) the actual work delivered, and (b) the optimum shaft work, in Btu/lb.