Chapters 5, 6, and 7

Use T_0 = 20 C and p_0 = 100 kPa and constant specific heats unless otherwise noted. Note also that 1 bar = 100 kPa.

5 - 1. Steam enters a steady-flow device at 16 MPa and 560 °C with a velocity of 80 m/s. At the exit the fluid is a saturated vapor at 70 kPa and the area is 1000 cm^2. If the mass flow rate is 1000 kg/min, determine (a) the inlet area, in square centimeters, and (b) the outlet velocity, in m/s.

5 - 2. Refrigerant R134a enters a steady-state control volume at 500 kPa and 100°C where the entrance diameter of the inlet pipe is 0.10 m and the flow velocity is 7.0 m/s. At the exit of the control volume the pressure has reached 60 kPa and the quality of the fluid is 70 percent. If the exit diameter is 0.20 m, determine (a) the mass flow rate, in kg/s, and (b) the exit flow velocity, in m/s.

5 - 3. A compressor is designed with inlet conditions of 240 kPa and 0 °C for the entering refrigerant R134a. A mass flow rate of 2.0 kg/min is to be used. If the inlet velocity of the refrigerant is not to exceed 10 m/s, (a) determine the smallest internal diameter of tubing that can be used, in centimeters, (b) If the outlet temperature and pressure are 50 °C and 800 kPa, respectively, and the outlet tubing is the same size as the inlet tubing, determine the exit velocity, in m/s.

5 - 4. Air initially at 0.15 MPa and 80 °C flows through an area of 100 cm^2 at a rate of 50 kg/min. Downstream at another position the pressure is 0.25 MPa, the temperature is 100 °C, and the velocity is 20 m/s. Determine (a) the inlet velocity, in m/s, and (b) the outlet area, in square centimeters.

5 - 5. Air flows through a pipe with a variable cross section. At the pipe inlet the pressure is 600 kPa, the temperature is 27 °C, the area is 35.0 cm^2, and the velocity is 60 m/s. Al the pipe exit the conditions are 500 kPa and 50 °C, and the cross-sectional area is 20.0 cm^2. Find (a) the mass flow rate, in kg/s, and (b) the exit velocity, in m/s.

5 - 6. Carbon dioxide enters a steady-flow device at 27 °C with a velocity of 25 m/s through an area of 4800 cm^2. At the exit of the device, the pressure and temperature are 0.14 MPa and 47 °C, respectively, and the gas moves with a velocity of 9 m/s through an area of 7500 cm^2. Determine (a) the mass flow rate, in kg/s, and (b) the inlet pressure, in MPa. Assume ideal-gas behavior.

5 - 7. Air enters a diffuser at 70 kPa, 57 °C, with a velocity of 200 m/s. At the outlet, where the area is 20 percent greater than at the inlet, the pressure is 100 kPa. Determine the outlet temperature, in degrees Celsius, and the outlet velocity, in m/s, if (a) the process is adiabatic, and (b) the fluid loses 40 kJ/kg by heat transfer as it passes through the diffuser.

5 - 8. Steam enters an adiabatic diffuser as a saturated vapor at 110 °C with a velocity of 220 m/s. At the exit the pressure and temperature are 150 kPa and 120 °C, respectively. If the exit area is 50 cm^2, determine (a) the exit velocity, in m/s, and (b) the mass flow rate, in kg/s.

5 - 9. Steam enters a nozzle at 3000 kPa and 320 °C and leaves at 1500 kPa with a velocity of 535 m/s. The mass flow rate is 8000 kg/h. Neglecting the inlet velocity and considering adiabatic flow, compute (a) the exit enthalpy, in kJ/kg, (b) the exit temperature, in degrees Celsius, and (c) the nozzle exit area, in square centimeters.

5 - 10. Steam at 1000 kPa, 200 °C, enters an adiabatic nozzle with a velocity of 20 m/s. The exit conditions are 700 kPa and 180 °C. Determine the ratio of inlet to exit areas, A_1/A_2.

5 - 11. Air is admitted to an adiabatic nozzle at 300 kPa, 200°C, and 50 m/s. The exit conditions are 200 kPa, and 150 °C. Determine the ratio of the exit area to the entrance area, A_2/A_1.

5 - 12. Air expands through a nozzle from 25 psia, 200 °F, to 15 psia, 80 °F. If the inlet velocity is 100 ft/s and the heat loss is 2.0 Btu/lb_m, find (a) the exit velocity, in ft/s, and (b) the ratio of the inlet area to the exit area.

5 - 13. Air enters a nozzle at 180 kPa, 67 °C, and 48 m/s. At the outlet the pressure is 100 kPa and the velocity is six times its initial value. If the inlet area is 100 cm^2, determine (a) the exit area of the adiabatic nozzle, in square centimeters, and (b) the outlet temperature, in degrees Celsius.

5 - 14. Steam flows steadily through a turbine at 20,000 kg/h, entering at 4000 kPa, 440°C, and leaving at 20 kPa with 90 percent quality. A heat loss of 20 kJ/kg occurs. The inlet pipe has a 12 cm diameter, and the exhaust section is rectangular with dimensions of 0.6 by 0.7 m. Calculate (a) the kinetic energy change, and (b) the power output, in kilowatts.

5 - 15. Steam flows steadily through a turbine at 300,000 lb_m/h, entering at 700 psia, 700 °F, and leaving at 1 psia as a saturated vapor. A heat loss of 4 Btu/lb_m occurs. The inlet pipe has a 12-in diameter, and the exhaust section is rectangular with dimensions of 6.0 by 7.0 ft. Calculate (a) the kinetic-energy change, in Btu/lb_m, and (b) the power output, in horsepower.

5 - 16. A steam turbine develops 10,000 kW of power from a flow rate of 42,000 kg/h. The steam enters at 4000 kPa and leaves at 4 kPa with a quality of 92 percent. Assume negligible

heat transfer and change in kinetic energy. Calculate (a) the inlet temperature in degrees Celsius, and (b) the exit area, in square meters, if the exit velocity is 140 m/s.

5 - 17. Air enters a turbine at 6 bars, 740 K, and 120 m/s. The exit conditions are 1 bar, 450 K, and 220 m/s. A heat loss of15 kJ/kg occurs, and the inlet area is 4.91 cm^2. Determine (a) the kinetic energy change, in kJ/kg, (b) the power output, in kilowatts, and (c) the ratio of the inlet-to outlet-pipe diameters.

5 - 18. Carbon dioxide is to be compressed from 0.1 MPa, 310 K to 0.5 MPa, 430 K. The required volume flow rate at inlet conditions is 30m^3/min. The kinetic-energy change is negligible, but a heat loss of 4 kJ/kg occurs. Determine the required power input, in kilowatts.

5 - 19. An air compressor handling 300 m^3/min increases the pressure from 1.0 bar to 2.3 bars, and heat is removed at the rate of 1700 kJ/min. The inlet temperature and area are 17 °C and 280 cm^2, respectively, and these values for the exit are 137 °C and 200 cm^2. Find (a) the inlet and exit velocities in m/s, and (b) the required power input, in kW.

5 - 20. A fan receives air at 970 mbar, 20 °C, and 3 m/s, and discharges it at 1020 mbar, 2I.6 °C, and 18 m/s. If the flow is adiabatic and 50 m^3/min enters, determine the power input, in kilowatts.

5 - 21. A steam compressor is supplied with 50 kg/h of saturated vapor at 0.04 bar and discharges at 1.5 bar and 120 °C. The power required is measured to be 2.4 kW. What is the rate of heat transfer from the steam, in kJ/min?

5 - 22. Steam flows through a heavily insulated throttling valve under the following conditions: (a) enters at 30 bars, 240 °C, and exhausts at 7 bars, (b) enters at 280 bars, 480°C, and exits at 200 bars, and (c) enters as saturated vapor at 8 bars and exits at 3 bars. Determine the final temperature downstream from the valve at the stated exit pressure, in degrees Celsius.

5 - 23. Refrigerant 134a is throttled from (a) 50 °C and 1.2 MPa to a final pressure of 280 kPa; determine the final temperature in °C (b) saturated liquid (x=0) and 400 kPa to a final pressure of 100 kPa; determine the final temperature and quality (c) a saturated vapor at 1600 kPa to a final pressure of 100 kPa; determine the final temperature in °C and the specific volume in m^3/kg?

5 - 24. Dry air enters an air conditioning system at 30 °C and 0.11 MPa at a volume flow rate of 1.20 m^3/s. The air is cooled by exchanging heat with a stream of refrigerant 134a which enters the heat exchanger at 10 °C and a quality of 20 percent. Assume the heat transfer takes place at constant pressure for both flow streams. The refrigerant leaves as a saturated vapor, and

22 kJ/s of heat is removed from the air. Find (a) the flow rate of refrigerant 12 required, in kg/s, and (b) the temperature of the air leaving the heat exchanger.

5 - 25. Water at 5 bars and 140 °C enters a heat exchanger at a rate of 240 kg/min and leaves at 4.8 bars and 60 °C. The water is cooled by passing air through the heat exchanger at an inlet volume flow rate of 1000 m^3/min. The air initially is at 1.10 bars and 25 °C, and the exit pressure is 1.05 bars. Determine (a) the exit air temperature in degrees Celsius, (b) the inlet area for airflow, in m^2, if the inlet air velocity is 25 m/s, and (c) the inlet water velocity, in m/s, if the inlet-pipe diameter is 10 cm,

5 - 26. Water substance is fed into a mixing chamber from two different sources. One source delivers steam of 90 percent quality at a rate of 2000 kg/h. The second source delivers steam at a temperature of 280 °C and a rate of (a) 1750 kg/h, and (b) 2790 kg/h. If the mixing process is adiabatic and at a constant pressure of 10 bars, determine the temperature of the mixture at equilibrium downstream from the chamber.

5 – 27. A thermodynamics student would like to calculate the mass flow rate ratio of cold water to hot water in his/her morning shower. He/she closes the hot water valve, opens the cold water valve and measures the cold water temperature at 10 C; then he/she closes the cold water valve, opens the hot water valve, and measures the hot water temperature at 80 C. While taking the shower, he/she measures temperature of the water and flow rate of the water from the showerhead (with a thermometer, bucket, and stopwatch) at 55 C and about 5 gallons (20 liters) per minute. Calculate the mass flow rate of the cold water in kg/s and the mass flow rate ratio of hot water to cold water. (Hint: use $h \approx h_{f@T}$)

5 - 28. An open feedwater heater operates at 7 bars. Compressed liquid water at 35 °C enters one section. Determine the temperature of steam entering another section if the ratio of the mass flow rate of compressed liquid to superheated vapor is (a) 4.52:1, and (b) 4.37:1.

5 - 29. A long, horizontal pipe with an internal diameter of 5.25 cm carries refrigerant 134a. The fluid enters at 3.2 bars with a quality of 40 percent and a velocity of 3 m/s. The fluid leaves the pipe at 2.8 bars and 20 °C. Determine (a) the mass flow rate, in kg/s, (b) the exit velocity, in m/s, and (c) the heal transfer rate, in kJ/s.

5 - 30. Oil with a specific gravity of 0.90 enters a piping system at 0.240 MPa, 15 °C, and 6.0 m/s. Downstream the conditions are I5 °C and 4 m/s at an elevation which is 8.0 m below the inlet. The local gravity is 9.65 m/s^2, and the fluid gains 0.0079 kJ/kg as heat as it passes through the system at a mass flow rate of 2000 kg/min. Determine (a) the outlet pressure, in MPa, and (b) the outlet-pipe diameter, in cm.

5 – 31. In an air conditioning ductwork system above the ceiling of a classroom cold air enters at mixing chamber at 10 C and 100 kPa at a rate of 0.5 m^3/s while warm air enters the chamber at 40 C and 100 kPa. The conditioned air leaves the chamber and vents into the room below at 24 C. Determine the mass flow rate of the warm air entering the mixing chamber.

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6 - 1. At what temperature is heat supplied to a Carnot engine that rejects 1000 kJ/min of heat at 7 °C and produces (a) 40 kW of power, and (b) 50 kW of power?

6 - 2. An ocean thermal-energy-conversion (OTEC) power plant uses the waters' naturally occurring temperature differences. (a) At a given location the surface temperature is 20 °C, and at a 700 m depth the value is -5 °C. Calculate the maximum net work output from a Carnot cycle per kilojoule of heat addition. (b) Assume the surface water experiences a 5 °C decrease during heat addition. Determine the required mass flow rate of seawater required, in kg/s, for a power output from the cycle of 100 MW.

7 - 1. One-tenth kilogram of steam at 3.0 bars and 200 °C is compressed isothermally to 15 bars in a piston-cylinder device. During this process 20,000 J of work is done on the gas, and heat is lost to the environment which is at 30 °C. Determine (a) the heat transfer, in kJ, (b) the entropy change of the steam, in kJ/K, and (c) the total entropy change for the overall process, in kJ/K. Is the process reversible, irreversible, or impossible?

7 - 2. Steam originally at 60 bars, 500 °C, is expanded isothermally and reversibly to 15 bars in a steady-flow device. Heat is supplied to the steam from a reservoir at 550 °C. Determine (a) the heat transfer and the work output, in kJ/kg, and (b) the total entropy change for the process in kJ/kgK. Is the process reversible, irreversible, or impossible? Sketch the process on a Ts diagram.

7 - 3. A piston-cylinder device contains air at 350 K and 1 bar. The pressure is increased to 1.3 bars, but during the process heat transfer occurs so that the temperature remains constant. (a) Determine the entropy change of the air, in kJ/kgK. (b) If the temperature of the surroundings is 300 K, determine the entropy change of the surroundings, in kJ/kgK. (c) Is the increase in entropy principle fulfilled?

7 - 4. Contained in a constant-pressure closed system is 0.5 Ib_m of hydrogen gas at 100 psia and 40 °F. Heat in the amount of 520 Btu is added to the gas from a reservoir at 550 °F. Compute (a) the entropy change of the hydrogen, in Btu/R, and (h) the total entropy change for the overall process, in Btu/R. (c) Is the process reversible, irreversible, or impossible?

7 - 5. Air, in the amount of 0.5 lb_m, in a constant-volume system has an initial state of 5.0 ft^3 and 80 °F. Measurements during the process indicate that 4.5 Btu of heat were removed and paddle-wheel work was carried out by applying a torque of 23.9 ft lb_f to the shaft for 50 revolutions. Find (a) the final temperature of the gas in the tank, in degrees Fahrenheit, (b) the entropy change of the air, in Btu/R, and (c) the total entropy change of the overall process, in Btu/R, if the temperature of the environment to which heat is transferred is 70 °F.