Problem Set 4 Exergy and Irreversibility

8–18 A heat engine receives heat from a source at 1500 K at a rate of 700 kJ/s, and it rejects the waste heat to a medium at 320 K. The measured power output of the heat engine is 320 kW, and the environment temperature is 25°C. Determine (*a*) the reversible power, (*b*) the rate of irreversibility, and (*c*) the second-law efficiency of this heat engine. *Answers:* (*a*) 550.7 kW, (*b*) 230.7 kW, (*c*) 58.1 percent

8–23 A house that is losing heat at a rate of 80,000 kJ/h when the outside temperature drops to 15°C is to be heated by electric resistance heaters. If the house is to be maintained at 22°C at all times, determine the reversible work input for this process and the irreversibility. *Answers:* 0.53 kW, 21.69 kW

8–31 The radiator of a steam heating system has a volume of 20 L and is filled with superheated water vapor at 200 kPa and 200°C. At this moment both the inlet and the exit valves to the radiator are closed. After a while it is observed that the temperature of the steam drops to 80°C as a result of heat transfer to the room air, which is at 21°C. Assuming the surroundings to be at 0°C, determine (*a*) the amount of heat transfer to the room and (*b*) the maximum amount of heat that can be supplied to the room if this heat from the radiator is supplied to a heat engine that is driving a heat pump. Assume the heat engine operates between the radiator and the surroundings. *Answers:* (*a*) 30.3 kJ, (*b*) 116.3 kJ

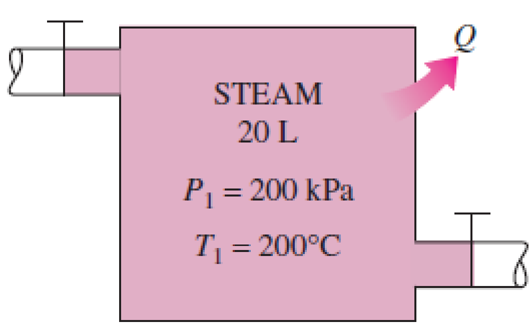


FIGURE P8–31

8–29 A piston–cylinder device initially contains 2 L of air at 100 kPa and 25°C. Air is now compressed to a final state of 600 kPa and 150°C. The useful work input is 1.2 kJ. Assuming the surroundings are at 100 kPa and 25°C, determine (*a*) the exergy of the air at the initial and the final states, (*b*) the minimum work that must be supplied to accomplish this compression process, and (*c*) the second-law efficiency of this process. *Answers:* (*a*) 0, 0.171 kJ, (*b*) 0.171 kJ, (*c*) 14.3 percent

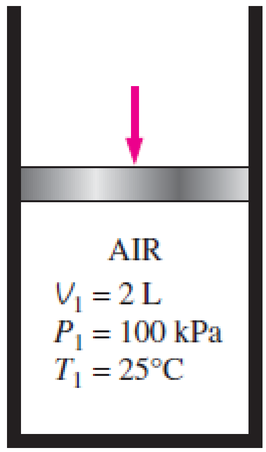


FIGURE P8–29

8–43 An insulated rigid tank is divided into two equal parts by a partition. Initially, one part contains 3 kg of argon gas at 300 kPa and 70°C, and the other side is evacuated. The partition is now removed, and the gas fills the entire tank. Assuming the surroundings to be at 25°C, determine the exergy destroyed during this process. *Answer:* 129 kJ

8–49 An ordinary egg can be approximated as a 5.5-cm-diameter sphere. The egg is initially at a uniform temperature of 8°C and is dropped into boiling water at 97°C. Taking the properties of egg to be $\rho = 1020 \text{ kg/m}^3$ and $c_p = 3.32 \text{ kJ/kg} \cdot °\text{C}$, determine how much heat is transferred to the egg by the time the average temperature of the egg rises to 70°C and the amount of exergy destruction associated with this heat transfer process. Take $T_0 = 25°\text{C}$.

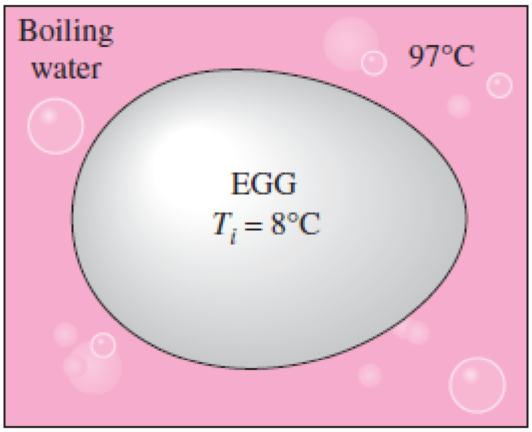
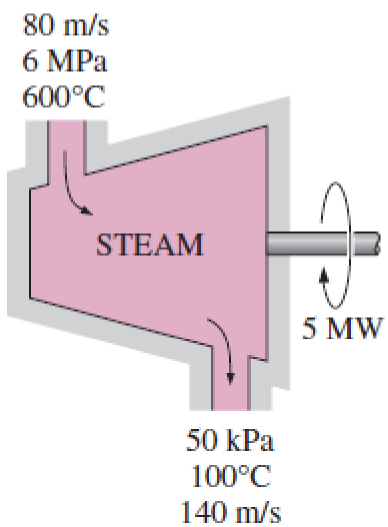


FIGURE P8–49

8–63 Steam enters an adiabatic turbine at 6 MPa, 600°C, and 80 m/s and leaves at 50 kPa, 100°C, and 140 m/s. If the power output of the turbine is 5 MW, determine (*a*) the reversible power output and (*b*) the second-law efficiency of the turbine. Assume the surroundings to be at 25°C.
Answers: (*a*) 5.84 MW, (*b*) 85.6 percent



8–64 Steam is throttled from 9 MPa and 500°C to a pressure of 7 MPa. Determine the decrease in exergy of the steam during this process. Assume the surroundings to be at 25°C.
Answer: 32.3 kJ/kg

8–77 Liquid water at 200 kPa and 20°C is heated in a chamber by mixing it with superheated steam at 200 kPa and

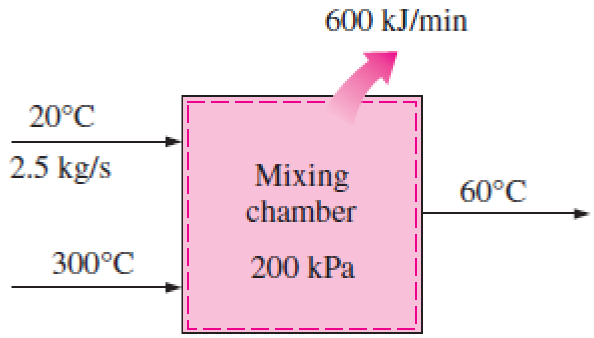


FIGURE P8–77

300°C. Liquid water enters the mixing chamber at a rate of 2.5 kg/s, and the chamber is estimated to lose heat to the surrounding air at 25°C at a rate of 600 kJ/min. If the mixture leaves the mixing chamber at 200 kPa and 60°C, determine (*a*) the mass flow rate of the superheated steam and (*b*) the wasted work potential during this mixing process.

8–80 A 0.6-m^3 rigid tank is filled with saturated liquid water at 170°C. A valve at the bottom of the tank is now opened, and one-half of the total mass is withdrawn from the tank in liquid form. Heat is transferred to water from a source of 210°C so that the temperature in the tank remains constant. Determine (*a*) the amount of heat transfer and (*b*) the reversible work and exergy destruction for this process. Assume the surroundings to be at 25°C and 100 kPa.
Answers: (*a*) 2545 kJ, (*b*) 141.2 kJ, 141.2 kJ

8–135 Steam is to be condensed in the condenser of a steam power plant at a temperature of 60°C with cooling water from a nearby lake that enters the tubes of the condenser at 15°C at a rate of 140 kg/s and leaves at 25°C. Assuming the condenser to be perfectly insulated, determine (*a*) the rate of condensation of the steam and (*b*) the rate of exergy destruction in the condenser. *Answers:* (*a*) 2.48 kg, (*b*) 694 kW

8–136 A well-insulated heat exchanger is to heat water (c_p = 4.18 kJ/kg · °C) from 25°C to 60°C at a rate of 0.4 kg/s. The heating is to be accomplished by geothermal water (c_p = 4.31 kJ/kg · °C) available at 140°C at a mass flow rate of 0.3 kg/s. The inner tube is thin-walled and has a diameter of 0.6 cm. Determine (*a*) the rate of heat transfer and (*b*) the rate of exergy destruction in the heat exchanger.

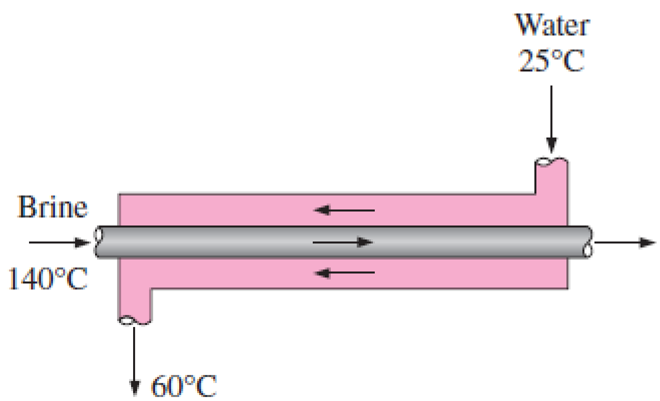


FIGURE P8–136

8–101 One method of passive solar heating is to stack gallons of liquid water inside the buildings and expose them to the sun. The solar energy stored in the water during the day is released at night to the room air, providing some heating. Consider a house that is maintained at 22°C and whose heating is assisted by a 350-L water storage system. If the water is heated to 45°C during the day, determine the amount of heating this water will provide to the house at night. Assuming an outside temperature of 5°C, determine the exergy destruction associated with this process. *Answers:* 33,548 kJ, 1172 kJ

8–36 An insulated piston–cylinder device contains 2 L of saturated liquid water at a constant pressure of 150 kPa. An electric resistance heater inside the cylinder is turned on, and electrical work is done on the water in the amount of 2200 kJ. Assuming the surroundings to be at 25°C and 100 kPa, determine (*a*) the minimum work with which this process could be accomplished and (*b*) the exergy destroyed during this process. *Answers:* (*a*) 437.7 kJ, (*b*) 1705 kJ

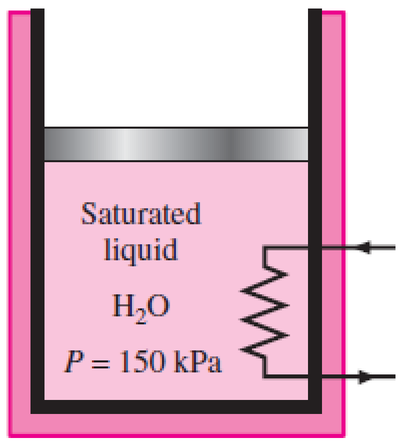


FIGURE P8–36