A domestic water heater holds 189 L of water at 60°C, 1 atm. Determine the exergy of the hot water, in kJ. To what elevation, in m, would a 1000-kg mass have to be raised from zero elevation relative to the reference environment for its exergy to equal that of the hot water? Let $T_o = 298$ K, $p_o = 1$ atm, $g = 9.81$ m/s².

Refrigerant 134a initially at −36°C fills a rigid vessel. The refrigerant is heated until the temperature becomes 25°C and the pressure is 1 bar. There is no work during the process. For the refrigerant, determine the heat transfer per unit mass and the change in specific exergy, each in kJ/kg. Comment. Let $T_o = 20$°C, $p_o = 0.1$ MPa.

A radiator of a steam heating system has a volume of 20 L and is filled with superheated water vapor at 300 kPa and 200°C (State 1). 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 (State 2) as a result of heat transfer to the room air, which is at 21°C. Assume surrounding temperature is 0°C. Determine:

(a) the amount of heat transfer to the room, in kJ.
(b) the maximum theoretical work that can be obtained during the process from State 1 to 2, in kJ.

Suppose a reversible heat pump operates between the surrounding temperature of 0°C and room temperature of 21°C. Calculate:

(c) the maximum heat transfer deliverable to the room, in kJ.

Answers: (a) -52 kJ; (c) 209.9 kJ
A rigid tank of 1 m³ initially contains a mixture of saturated R134a vapor and liquid at a temperature of 20°C and a quality of 0.1 (State 1). A leak develops and saturated vapor slowly escapes from the top. The leak is stopped at the moment when all of the liquid has evaporated (State 2). Heat transfer occurs so that the temperature remains constant. The environmental temperature is 30°C.

(a) Find the mass of R134a which has escaped, in kg.
(b) Find the total heat transfer for the process, in kJ.
(c) Find the exergy destroyed in the entire system, in kJ.
Steady-state operating data are shown in Fig. P7.50 for an open feedwater heater. Heat transfer from the feedwater heater to its surroundings occurs at an average outer surface temperature of 50°C at a rate of 100 kW. Ignore the effects of motion and gravity and let \( T_0 = 25°C, \ p_0 = 1 \) bar. Determine

a. the ratio of the incoming mass flow rates, \( \dot{m}_1/\dot{m}_2 \).

b. the rate of exergy destruction, in kW.

![Diagram of feedwater heater](image)

---

**Problem 7.53**

Steam at 30 bar and 700°C is available at one location in an industrial plant. At another location, steam at 20 bar and 400°C is required for use in a certain process. An engineer suggests that steam at this condition can be provided by allowing the higher-pressure steam to expand through a valve to 20 bar and then cool to 400°C through a heat exchanger with heat transfer to the surroundings, which are at 20°C.

a. Evaluate this suggestion by determining the associated exergy destruction rate per mass flow rate of steam (kJ/kg) for the valve and heat exchanger. Discuss.

b. Evaluating exergy at 8 cents per kW·h and assuming continuous operation at steady state, determine the total annual cost, in $, of the exergy destruction for a mass flow rate of 1 kg/s.

c. Suggest an alternative method for obtaining steam at the desired condition that would be preferable thermodynamically, and determine the total annual cost, in $, of the exergy destruction for a mass flow rate of 1 kg/s. Let \( T_0 = 20°C, \ p_0 = 1 \) atm.
A compressed-air energy storage system fills an underground cavern with pressurized air. The cavern has a fixed volume of $10^5$ m$^3$ and initially contains air at an absolute pressure of 1 bar and temperature of 285 K (State 1) that is the same as the environment. After the filling process is complete, the cavern contains air at an absolute pressure of 20 bar and temperature of 800 K (State 2). The system boundary (control volume) includes the compressor, piping, and cavern. Molar mass of air is 28.97 kg/kmol.

(a) Find the initial and final mass of air in the cavern, in kg.
(b) Find the total work done by the compressor, in kJ.
(c) Find the total change in exergy contained within the cavern assuming that the filling process is reversible, in kJ.