

Contents

Pset2	2
Problem 1	2
a)	2
b)	4
Problem 2	5
a)	5
b)	5
c)	5
Problem 3	6
a)	6
b)	6
c)	7
d)	7

Pset2

Name: Divy Chandra

Cohort: SC06

Student ID: 1005246

Problem 1

a)

From Pset 1 Q3:

$$\Delta \dot{Q}_{5,6} = -6680 \text{ kW}, \quad \Delta \dot{W}_{5,6} = 0 \text{ W}$$

$$\Delta \dot{Q}_{2,3} = 6680 \text{ kW}, \quad \Delta \dot{W}_{2,3} = 0 \text{ W}$$

$$\Delta \dot{Q}_{1,2} = 0 \text{ kW}, \quad \Delta \dot{W}_{1,2} = -10,000 \text{ kW}$$

$$\Delta \dot{Q}_{3,4} = 0 \text{ kW}, \quad \Delta \dot{W}_{3,4} = 10569.24 \text{ kW}$$

Using the Entropy balance for all the above stages, one by one: $\frac{dS_{sys}}{dt} =$

$$\frac{\dot{Q}_{in}}{T_{in}} - \frac{\dot{Q}_{out}}{T_{out}} + \dot{m}(s_i - s_e) + \dot{\sigma}_{gen}$$

For the state going from 5 to 6:

$$\dot{Q}_{in} = 0 \text{ W}, \quad \dot{Q}_{out} = 0 \text{ kW}$$

$$\dot{T}_{in} = 1480 \text{ K}, \quad \dot{T}_{out} = 1200 \text{ K}$$

$$s_5^\circ = 3.42892 \text{ kJ/kg.K} \quad s_6^\circ = 3.17888 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_5 = 3.3428 \text{ kJ/kg.K} \quad s_6 = 3.17888 \text{ kJ/kg.K}$$

$$\dot{m} = 20 \text{ kg/s}$$

$$0 = 20(3.3428 - 3.17888) + \dot{\sigma}_{gen}$$

$$\dot{\sigma}_{gen} = -3.28 \text{ kJ/s.K}$$

(even though this value is negative, the total entropy generation for the heat exchanger is positive)

For the state going from 2 to 3:

$$\dot{Q}_{in} = 0 \text{ kW}, \quad \dot{Q}_{out} = 0 \text{ kW}$$

$$\dot{T}_{in} = 1100 \text{ K}, \quad \dot{T}_{out} = 1301.52 \text{ K}$$

$$s_2^\circ = 3.07732 \text{ kJ/kg.K} \quad s_3^\circ = 3.2748294 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_2 = 2.6154 \text{ kJ/kg.K} \quad s_3 = 2.8432 \text{ kJ/kg.K}$$

$$\dot{m} = 28.22 \text{ kg/s}$$

$$0 = 28.22(2.6154 - 2.8432) + \dot{\sigma}_{gen}$$

$$\dot{\sigma}_{gen} = 6.43 \text{ kJ/s.K}$$

Total entropy generated for the heat exchanger:

$$\dot{\sigma}_{gen} = 6.43 - 3.28 = 3.15 \text{ kJ/s.K}$$

For Turbine 1 (state 1 to 2):

$$\dot{Q}_{in} = 0 \text{ W}, \quad \dot{Q}_{out} = 0 \text{ kW}$$

$$\dot{T}_{in} = 1400 \text{ K}, \quad \dot{T}_{out} = 1100 \text{ K}$$

$$s_1^\circ = 3.36200 \text{ kJ/kg.K} \quad s_2^\circ = 3.07732 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_1 = 2.5022 \text{ kJ/kg.K} \quad s_2 = 2.6154 \text{ kJ/kg.K}$$

$$\dot{m} = 28.22 \text{ kg/s}$$

$$0 = \frac{0}{1400} - \frac{0}{1100} + 28.22(2.5022 - 2.6154) + \dot{\sigma}_{gen}$$

$$\dot{\sigma}_{gen} = 3.19 \text{ kJ/s.K}$$

For Turbine 2 (state 3 to 4):

$$\dot{Q}_{in} = 0 \text{ W}, \quad \dot{Q}_{out} = 0 \text{ kW}$$

$$\dot{T}_{in} = 1301.52 \text{ K}, \quad \dot{T}_{out} = 980 \text{ K}$$

$$s_3^\circ = 3.2748294 \text{ kJ/kg.K} \quad s_4^\circ = 2.94468 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_3 = 2.8432 \text{ kJ/kg.K} \quad s_4 = 2.94468 \text{ kJ/kg.K}$$

$$\dot{m} = 28.22 \text{ kg/s}$$

$$0 = \frac{0}{1301.52} - \frac{0}{980} + 28.22(2.8432 - 2.94468) + \dot{\sigma}_{gen}$$

$$\dot{\sigma}_{gen} = 2.86 \text{ kJ/s.K}$$

Entropy Generated from the heat exchanger (he) = $\dot{\sigma}_{gen,he} = 3.15kJ/s.K$

Entropy Generated from Turbine 1 (t1) = $\dot{\sigma}_{gen,t1} = 3.19kJ/s.K$

Entropy Generated from Turbine 2 (t2) = $\dot{\sigma}_{gen,t2} = 2.86kJ/s.K$

b)

The most inefficient component is the one that generates the most entropy. In decreasing order of amount of entropy generated (going from least efficient to most efficient), the components are:

Turbine 1, Heat Exchanger, Turbine 2

Problem 2

$$T_{out} = 0^\circ C, \quad T_{wall,out} = 5^\circ C, \quad T_{wall,in} = 20^\circ C, \quad T_{in} = 27^\circ C$$
$$L = 0.3m, \quad A = 30m^2, \quad \dot{Q} = 1035W$$

a)

$$\Delta \dot{X}_{work} = 0kW$$

$$\dot{X}_{heat,in} = (1 - \frac{T_0}{T})\dot{Q} = (1 - \frac{273}{293})1035 = 70.65kW$$

$$\dot{X}_{heat,out} = (1 - \frac{T_0}{T})\dot{Q} = (1 - \frac{273}{278})1035 = 18.62kW$$

$$\Delta \dot{X} = \Delta \dot{X}_{heat} + \Delta \dot{X}_{work} - \dot{X}_{destroyed}$$

$$0 = 70.65 - 18.62 - \dot{X}_{destroyed}$$

$$\dot{X}_{destroyed} = 52.03kW$$

b)

$$\Delta \dot{X}_{work} = 0kW$$

$$\Delta \dot{X}_{heat} = (1 - \frac{T_0}{T})\dot{Q} = (1 - \frac{273}{300})1035 = 93.15kW$$

(There is no X_{out} here, only X_{in})

$$\Delta \dot{X} = \Delta \dot{X}_{heat} + \Delta \dot{X}_{work} - \dot{X}_{destroyed}$$

$$0 = 93.15 - \dot{X}_{destroyed}$$

$$\dot{X}_{destroyed} = 93.15kW$$

c)

The exergy destroyed in the entire process is more than just the exergy destroyed during the conduction through the wall because it includes two additional convection processes that contribute to the total exergy destroyed which are not taken into account for heat transfer through just the wall. Thermal resistivity diagram:

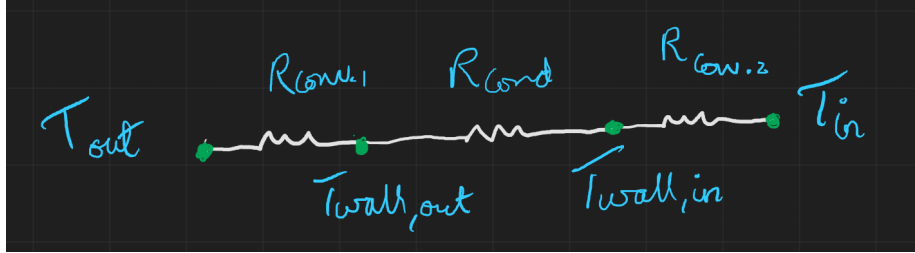


Figure 1: 2.2.c

Problem 3

From Problem 1

$$\dot{\sigma}_{gen,he} = 3.15 = kJ/s.K$$

$$\dot{\sigma}_{gen,t1} = 3.19 kJ/s.K$$

$$\dot{\sigma}_{gen,t2} = 2.86 kJ/s.K$$

a)

$$\dot{X}_{destroyed,he} = T_0 \dot{\sigma}_{gen,he} = 300 \times 3.15 = 945 \text{ kW}$$

$$\dot{X}_{destroyed,t1} = T_0 \dot{\sigma}_{gen,t1} = 300 \times 3.19 = 957 \text{ kW}$$

$$\dot{X}_{destroyed,t2} = T_0 \dot{\sigma}_{gen,t2} = 300 \times 2.86 = 858 \text{ kW}$$

$$\dot{X}_{destroyed,he} = 945 \text{ kW}$$

$$\dot{X}_{destroyed,t1} = 957 \text{ kW}$$

$$\dot{X}_{destroyed,t2} = 858 \text{ kW}$$

b)

$$\epsilon = 1 - \frac{\dot{X}_{destroyed}}{\dot{X}_{supplied}}$$

$$\dot{X}_{supplied} = m(\psi_{in} - \psi_{out})$$

$$\dot{X}_{supplied} = m((h_{in} - h_{out}) - T_0(s_{in} - s_{out}))$$

For Turbine 1 (The state going from 1 to 2):

$$s_1^\circ = 3.36200 \text{ kJ/kg.K} \quad s_2^\circ = 3.07732 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_1 = 2.5022 \text{ kJ/kg.K} \quad s_2 = 2.6154 \text{ kJ/kg.K}$$

$$h_1 = 1515.42 \text{ kJ/kg} \quad h_2 = 1161.07 \text{ kJ/kg}$$

$$X_{supplied} = 28.22((1515.42 - 1161.07) - 300(2.5022 - 2.6154)) = 10958.1082 \text{ kW}$$

$$\epsilon_1 = 1 - \frac{957}{10958.1082} = 0.91$$

$$\epsilon_1 = 0.91$$

For Turbine 2 (The state going from 3 to 4):

$$s_3^\circ = 3.2748294 \text{ kJ/kg.K} \quad s_4^\circ = 2.94468 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_3 = 2.8432 \text{ kJ/kg.K} \quad s_4 = 2.94468 \text{ kJ/kg.K}$$

$$h_3 = 1397.77804 \text{ kJ/kg} \quad h_4 = 1023.25 \text{ kJ/kg}$$

$$X_{supplied} = 28.22((1397.77804 - 1023.25) - 300(2.8432 - 2.94468)) = 11428.31 \text{ kW}$$

$$\epsilon_2 = 1 - \frac{858}{11428.31} = 0.92$$

$$\epsilon_2 = 0.92$$

$$\text{Efficiency of Turbine 1} = \epsilon_1 = 0.91$$

$$\text{Efficiency of Turbine 2} = \epsilon_2 = 0.92$$

c)

For Heat Exchanger (The state going from 5 to 6):

$$s_5^\circ = 3.42892 \text{ kJ/kg.K} \quad s_6^\circ = 3.17888 \text{ kJ/kg.K}$$

After applying the pressure correction for specific entropy:

$$s_5 = 3.3428 \text{ kJ/kg.K} \quad s_6 = 3.17888 \text{ kJ/kg.K}$$

$$h_5 = 1611.79 \text{ kJ/kg} \quad h_6 = 1277.79 \text{ kJ/kg}$$

$$X_{supplied} = 20((1611.79 - 1277.79) - 300(3.3428 - 3.17888)) = 5696.48 \text{ kW}$$

$$\epsilon_{he} = 1 - \frac{945}{5696.48} = 0.83$$

$$\text{Efficiency of the heat exchanger} = \epsilon_{he} = 0.83$$

d)

For the overall system,

$$\text{Total } X_{destroyed} = 945 + 958 + 858 = 2761 \text{ kW}$$

$$X_{supplied} = X_{supplied,process} + X_{supplied,he} \text{ kW}$$

$$X_{supplied} = \dot{m}(h_1 - h_4 - T_0(s_1 - s_4)) + X_{supplied,he} \text{ kW}$$

$$X_{supplied} = 28.22(1515.42 - 1023.25 - 300(2.5022 - 2.94468)) + 5696.48 = 23331.55 \text{ kW}$$

$$\epsilon = 1 - \frac{2761}{23331.55} = 0.88$$

$$\text{Efficiency} = \epsilon = 0.88$$