Varmafræði - Skiladæmi 6

Q1*

$dW = -32\ kW$, $T_{sys} = 301\ K$, $T_{surr} = 290\ K$

First law of thermodynamics gives

$$dQ = dU + dW$$

$$\Rightarrow dQ = 0 - 32\ kW = -32\ kW$$

Rate of entropy change:

$$\Delta S_{air} = \frac{dQ}{T_{sys}} = \frac{-32\ kW}{301\ K} = -0{,}106\ \frac{kW}{K}$$

Q6*

Rigid tank, $T_{tank} = 78 + 273 = 351\ K$, $P_{tank} = 1{,}8\ MPa$, $V = 15\ m^3$

$P_{out} = 101{,}325\ kPa$, $T_{out} = 351\ K$, $R_{argon} = 0{,}2081\ \frac{kJ}{kg\,K}$

Assuming ideal gas we know that for constant temperature

$$W = mRT \cdot \ln\left(\frac{P_1}{P_2}\right)$$

For the tank:

$$PV = mRT \Rightarrow m = \frac{P_{tank}V}{R_{argon}T_{tank}} = 3696{,}4\ kg$$

Now using the equation above, we obtain

$$W = 3696{,}4\ kg \cdot 0{,}2081\ \frac{kJ}{kg\,K} \cdot 351\ K \cdot \ln\left(\frac{1800\ kPa}{101{,}325\ kPa}\right)$$

$$\simeq 776\,846\ J = 0{,}777\ MJ$$

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Q4* $P_1 = 2,5\ MPa$, $P_2 = 500\ kPa$, $P_3 = 50\ kPa$

$T_3 = 100°C = 373\ K$

$\dot{m}_1 = 3,5\ kg/s$

Amount diverted

$$\dot{m}_2 = \dot{m}_1 \cdot 8\% = 0,28\ kg/s$$

Amount exhausted

$$\dot{m}_3 = \dot{m}_1 - \dot{m}_2 = 3,22\ kg/s$$

From table A6 we obtain for state 3:

$$h_{@100°C,\,50kPa} = 2682,4\ \frac{kJ}{kg} \quad \text{and} \quad s_{@100°C,\,50kPa} = 7,6953\ \frac{kJ}{kg\,K}$$

Now we know that $s_1 = s_2 = s_3$ because the process is isentropic.

For state 2 using interpolation:

$$h_{2@500kPa} = 3168,1\ \frac{kJ}{kg} + (3272,4 - 3168,1)\frac{kJ}{kg} \cdot \left(\frac{7,6953 - 7,6346}{7,7956 - 7,6346}\right)$$

$$= 3207,2\ \frac{kJ}{kg}$$

Same for state 1:

$$h_{1@2,5MPa} = 3686,8\ \frac{kJ}{kg} + (3915,2 - 3686,8)\frac{kJ}{kg} \cdot \left(\frac{7,6953 - 7,5979}{7,8455 - 7,5979}\right)$$

$$= 3776,7\ \frac{kJ}{kg}$$

Now we know that $\dot{W}_{out} = \dot{m}_1 h_1 - \dot{m}_2 h_2 - \dot{m}_3 h_3$

$$\approx 3683,1\ kW$$

Q8*

$V_{water} = 40L = 0,04 m^3, \quad T_{water,0} = 278 K, \quad T_{water,1} = 290 K$

$W_{in} = 3 kW, \quad V_{room} = 50 m^3, \quad T_{room,0} = 278 K, \quad T_{room,1} = 295 K$

$W_{out} = 1,2 kW, \quad \rho_{air} = 1,225 \frac{kg}{m^3}, \quad c_v = 0,718 \frac{kJ}{kgK}$

a)

$$Q_W = 0,04 m^3 \cdot 1000 \frac{kg}{m^3} \cdot 4,18 \frac{kJ}{kgK} \cdot (290-278)K = 2006,4 kJ$$

$$Q_A = 1,225 \frac{kg}{m^3} \cdot 50 m^3 \cdot 0,718 \frac{kJ}{kgK} \cdot (295-278)K = 747,62 kJ$$

then we have: $(W_{in} - W_{out}) \cdot \Delta t = Q_w + Q_A$

$$\Rightarrow \Delta t = \frac{Q_w + Q_A}{W_{in} - W_{out}} = \frac{(2006,4 - 747,62) kJ}{(3-1,2) kW} = 1530 \text{ sek}$$

$$= 25,5 \text{ min}$$

b)

Total heat loss: $Q_{out} = t \cdot W_{out} = 1530 s \cdot 1,2 \frac{kJ}{s}$

$= 1836 kJ$

Then we have:

$$S_{gen} = \Delta S_{sys} + \Delta S_{surr} = \frac{dQ}{T_{sys}} + \frac{dQ}{T_{surr}}$$

$$= \frac{-1836 kJ}{295 K} + \frac{1836 kJ}{278 K}$$

$$= 0,381 \frac{kJ}{K}$$

$$X_{destroyed} = T_{room,0} \cdot S_{gen} = 105,918 kJ$$

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d)

First we find:

$$COP_{rev} = \frac{1}{\frac{T_H}{T_L} - 1} = \frac{1}{\frac{295 K}{278 K} - 1} = 16,35$$

Then we have

$$W_{in,rev} = \frac{Q_L}{COP_{rev}} = \frac{1836 \text{ kJ}}{16,35} = 112,38 \text{ kJ}$$

And

$$W_{u,in} = \dot{I} + W_{in,rev} = 105,918 \text{ kJ} + 112,38 \text{ kJ}$$

$$= 218,298 \text{ kJ}$$

Second law efficiency:

$$\eta_{II} = \frac{W_{in,rev}}{W_{u,in}} = \frac{112,38 \text{ kJ}}{218,298} = \underline{\underline{0,5148}}$$