Assignment 5

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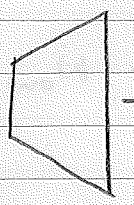
1. Steam enters
3.0 MPa
500°C
7m/s



Exits
0.3 MPa
140 m/s

$\dot{W} = 667$ kJ/kg

State	T(°C)	P(MPa)	V(m³/kg)	h(kJ/kg)	s(kJ/kg·K)	x
1	500	3.0	0.11620	3457.2	7.2359	Super. Heated
2		0.3				

$$\Delta \dot{E} = (\dot{W}_{IN} - \dot{W}_{out}) + (\dot{Q}_{IN} - \dot{Q}_{out}) + \dot{m}(h_{out} - h_{IN})$$

$$0 = 667 \text{ kJ/kg} + 0 + \left[\dot{m}_f\left(h_f + \frac{V_f^2}{2} + g\cancel{z_2}^{\,0}\right) - \dot{m}_i\left(h_i + \frac{V_i^2}{2} + \cancel{gz_1}^{\,0}\right)\right]$$

$$0 = 667 \text{ kJ/kg} + \left[(1 \text{ kg/s})\left(h_f + \frac{(140)^2}{2}\right) - (1 \text{ kg/s})\left(h_i + \frac{(70)^2}{2}\right)\right]$$

$$0 = 667 \text{ kJ/kg} + \left[h_f + 9.80 \text{ kJ/kg} - (3457.2 + 2.450)\right]$$

$$h_f = 2782.85 \text{ kJ/kg}$$ ✓

h	s
2761.2	7.0792
2782.85	s
2865.9	7.3132

$$\frac{7.0792 - s}{2761.2 - 2782.85} = \frac{7.0792 - 7.3132}{2761.2 - 2865.9}$$

$$s = 7.1275 \text{ kJ/kg·K}$$ ✓

$$\Delta S = \int \left(\frac{d\dot{Q}}{T}\right)_b + \dot{m}(s_{IN} - s_{out}) + P$$

$$0 = (1 \text{ kg/s})(7.2351 - 7.1275) + P$$

$$P = -0.1084$$ ✓

Negative entropy ⇒ impossible.

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Q. 1 (15/15)

a) T_{hot} — R_1 R_2 R_3 R_4 R_5 R_6 R_7 R_8 R_9 R_{10} — T_{cold}

$$R_{fabric} = R_1 = R_3 = R_5 = R_7 = R_9 = \frac{t}{kA} = \frac{0.0001\,m}{(0.13)(1.1\,m^2)} = 0.000693\,^\circ C/W$$

$$R_{air} = R_2 = R_4 = R_6 = R_8 = \frac{t}{kA} = \frac{0.0015\,m}{(0.026)(1.1\,m^2)} = 0.052448\,^\circ C/W$$

$$R_{10} = \frac{1}{hA} = \frac{1}{(25)(1.1\,m^2)} = 0.036364\,^\circ C/W$$

$$R_{total} = 5R_{fabric} + 4R_{air} + R_{10} = 0.250\,^\circ C/W \checkmark$$

$$\dot{q} = \frac{\Delta T}{R_{total}} = \frac{28-(-5)}{0.250} = 132\ W \checkmark$$

b) T_{hot} — R_1 R_2 — T_{cold}

$$R_{fabric} = R_1 = \frac{t}{kA} = \frac{0.0005\,m}{(0.13)(1.1\,m^2)} = 0.0034965\,^\circ C/W$$

$$R_2 = 0.036364\,^\circ C/W$$

$$R_{total} = R_{fabric} + R_2 = 0.0399\,^\circ C/W$$

$$\dot{q} = \frac{28-(-5)}{0.0399} = 827\ W \checkmark$$

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c) $R_{total} = 0.250\,^\circ C/W = R_{wool} + 0.036364\,^\circ C/W$

$\therefore R_{wool} = 0.214\,^\circ C/W$

$$R_{wool} = \frac{t}{kA} = \frac{t}{(0.035)(1.1\,m^2)} \rightarrow t = 0.00824\,m = 8.24\,mm \checkmark$$

Q. 2 Given: 1m x 1m plate $n = 166 \times 166 = 27556$ pins

$k = 237$ W/m.°C $T_\infty = 30°C$ $h = 35$ W/m².°C

$T_s = 100°C$ $q = h(A_b + \eta_f A_f)\theta_b$

$A_b = A_{base} - A_{fin\ base} = (1 \times 1) - (27556)\left(\frac{\pi(0.0025)^2}{4}\right)$

$= 0.86473\ m^2$

$A_f = 27556\left(\pi(0.0025)(0.17) + \frac{\pi(0.0025)^2}{4}\right)$

$= 36.927\ m^2$

$\varepsilon = (L + \frac{1}{4}D)\sqrt{2h/kD} = (0.17 + \frac{1}{4}(0.0025))\left(2(35)/(237)(0.0025)\right)^{1/2}$

$= 1.8546$

$\eta = 38\ \%$

$q = (35)(0.86473 + 0.38(36.927))(70)$

$= 36500\ W$

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$E_{fin} = \frac{q_{fin}}{q_{no\ fin}} = \frac{36500}{(35)(1 \times 1)(70)} = 14.9$

Q. 3 Given: $h = 425$ kJ/kg $D = 1.5$ m $\rho = 581$ kg/m³ $L = 4.0$ m

$T_1 = -42°C = 231\ K$

$T_\infty = 25°C = 298\ K$

$A_{tank} = \pi(1.5)(4) + 2\pi\left(\frac{1.5^2}{4}\right)$

$= 22.38\ m^2$

$\dot{Q}_{conv} = hA(T_s - T_\infty)$

$T_f = \frac{-42 + 25}{2} = -8.5°C$ $\beta = \frac{1}{(-8.5 + 273)} = 0.00378\ K^{-1}$

Air @ 264.5 K

$k = 0.0234$ W/m.°C (interpolated)

$\mu = 1.68 \times 10^{-5}$ kg/m.s (interpolated)

$Pr = 0.721$ (interpolated)

density of air @ ≈ -8.5°C

$Gr = \frac{g\beta(T_{surf.} - T_\infty)L^3\rho^2}{\mu^2} = \frac{(9.81)(0.00378)|(-42-25)|(1.5)^3(1.34)^2}{(1.68 \times 10^{-5})^2}$

$= 5.33 \times 10^{10}$

Q. 3 (continued)

$Gr Pr = 3.84 \times 10^{10}$

$C = 0.13 \quad n = 1/3$ (from Table C.8)

$Nu = C(GrPr)^n = 0.13(3.84\times10^{10})^{1/3}$ ✓

$= 439$ ✓

$Nu = \frac{hD}{k} = 439 = \frac{h(1.5)}{0.0234} \rightarrow h = 6.85 \text{ W/m}^2\cdot^\circ\text{C}$ ✓

$\dot{Q}_{conv} = (6.85)(22.38)(-42-25)$

$= -10300 \text{ W}$

$m_{propane} = \rho V = (581)\left(\frac{\pi(1.5)^2(4)}{4}\right)$

$= 4107 \text{ kg}$

$\dot{Q} = \dot{m} h_g = 10.3 \text{ kJ/s} = \dot{m}(425 \text{ kJ/kg})$

$\dot{m} = 0.0242 \text{ kg/s}$

$\Delta t = \frac{m}{\dot{m}} = \frac{4107}{0.0242} = 170{,}000 \text{ s}$

$= 47 \text{ hours}$ ✓

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