PTG exam 9 April 2014 short answers

123. Heat given off = surface * heat transfer coefficient * Δtemperature = A * h * ΔT

Heat transfer coefficient from Nu-number, which for natural convection depends on Gr-number

$Gr = \beta \cdot g \cdot L^3 \cdot \Delta T / \nu^2 = 1{,}09 \cdot 10^9$, with β given (~ 1/T), and L = 0.75 m. $Gr \cdot Pr = 0{,}78 \cdot 10^9 > 10^8$.

Nu (average for surface) = $0{,}13 \cdot (Gr \cdot Pr)^{1/3} = 119$ gives h (average for surface) = 4,14 $W/m^2 \cdot K$

Finally this gives with A = 2,25 m^2, heat given off = 186,3 W.

124. Using the steam tables for enthalpy values:

h_1 = 3023,5 kJ/kg ; h_2 = 3002,5 kJ/kg; h_3 = 226,0 + 0,9·2373,1 = 2361,8 kJ/kg; h_4 = 188,5 kJ/kg

a. Given off = $-Q_{1\text{-}2} = h_2 - h_1$ = 21,0 kJ/kg
b. Work out = $h_3 - h_2$ = 640,7 kJ/kg
c. Given off = $-Q_{3\text{-}4} = h_4 - h_3$ = -2173,3 kJ/kg
d. Heat input = $Q_{1\text{-}5} = h_1 - h_5 = h_1 - h_4$ + 4 (pump power) = 2831,0 kJ/kg
e. Efficiency = Work out / Heat input = 640,7 / 2831,0 = 0,226 = 22,6 %

Note: different steam tables may have different reference temperature/pressure for h = 0, but the differences between two enthalpy values should be the same.

125. a. heat balance: $(\text{mass flow*heat capacity})_b * \Delta T_b = (\text{mass flow*heat capacity})_w * \Delta T_w$

is also = $U \cdot A \cdot \Delta T_{lm}$, with ΔT_{lm} = 20°C, and, with $\Delta T_b = \Delta T_w$ and

$(\text{mass flow*heat capacity})_b = (\text{mass flow*heat capacity})_w = \dot{m} \cdot c_p$ (for "w" and "b") this gives

$U \cdot A = (40/28) \cdot \dot{m} \cdot c_p = (10/7) \cdot \dot{m} \cdot c_p$

b. Co-current: 1) heat transferred = $U \cdot A \cdot \Delta T_{lm} = U \cdot A \cdot (68 - (T_{out,w} - T_{out,b}))/\ln(68/(T_{out,w} - T_{out,b}))$

and 2) $\dot{m} \cdot c_p \cdot (T_{out,b} - 20) = \dot{m} \cdot c_p \cdot (80 - T_{w,out})$, giving $T_{out,w} = 108 - T_{out,b}$; into 1) gives $T_{out,b}$ = 52°C

126. a. Dissipated energy = volume flow * pressure drop = $\phi_v \cdot \Delta p$

Δp = ½·density·velocity^2·friction factor(·length/diameter for the tube sections) for 3 sections: upstream and downstream of pump + 2 bends.

Upstream: velocity = 0,99 m/s, Re = $5 \cdot 10^4$; friction factor 4f = ζ = 0,04 from Moody diagram;

downstream: velocity = 3,90 m/s, Re = 10^5; friction factor 4f = ζ = 0,04;

for the bends $K_w = \zeta'$ = 0,5 (given).

→ with volume flow = 0,002 m^3/s gives dissipated energy = $\phi_v \cdot \Delta p$ = 244 W

b. 244 W to heat up 2 kg/s water gives temperature rise 244 W /(2 kg/s·4200 J/kg·K) = 0,03 °C.

c. Power needed = 244 W for tube friction + mass flow · (g·Δheight + ½·($v^2_{out} - v^2_{in}$)) = 364 W, with Δheight = 5 m.