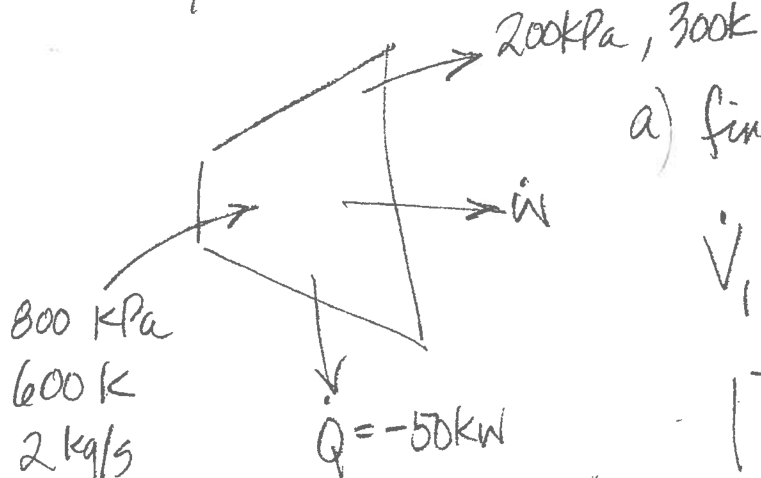
Practice problem solutions

1. Turbine, air



a) find $\dot{V}_1$, $\dot{V}_2$

$$\dot{V}_1 = \frac{\dot{m}}{\rho} = \frac{RT_1}{P_1}\dot{m} = \frac{0.287(600)2}{800}$$

$$\boxed{\dot{V}_1 = 0.43 \ m^3/s}$$

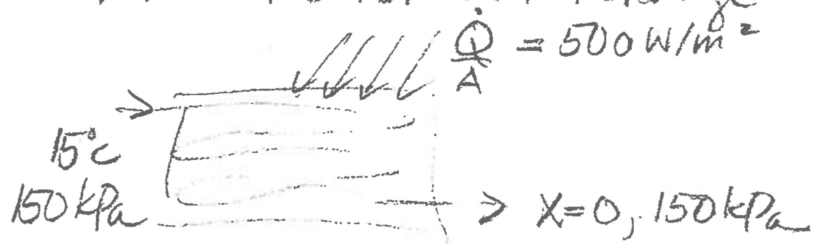
$$\dot{V}_2 = \frac{RT_2}{P_2}\dot{m} = \frac{0.287(300)2}{200} = \boxed{0.86 \ m^3/s}$$

b. 1st Law: $\dot{Q} - \dot{W} = \dot{m} C_p (T_2 - T_1)$ (neglect ke)

$$-\dot{W} = 2\frac{kg}{s}\left(1.005\frac{kJ}{kg K}\right)(300-600) + 50kW$$

$$-\dot{W} = -553 \ kW, \quad \boxed{\dot{W} = 553 \ kW}$$

2. solar collector heat exchange



$$\dot{V}_2 = 500\frac{L}{d} = 0.5\frac{m^3}{d}$$

$h_1 \approx h_f$ @ 15°C
$= 62.982$ kJ/kg

$h_2 = h_f$ @ 150kPa
$= 467.13$ kJ/kg

$v_f = 0.001053$ m³/kg

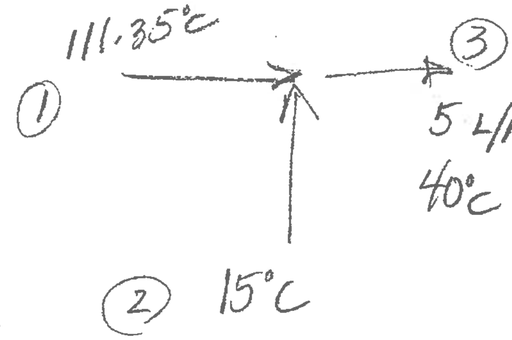
$$\frac{\dot{Q}}{A}(A) = \dot{m}(h_2 - h_1)$$

$$0.5 kW(A) = \frac{0.5 kg}{v_f \ d}(467.13 - 62.982)\frac{kJ}{kg} \cdot \frac{1d}{86400s}$$

$$A = \frac{1}{0.001053}\left(\frac{404.15}{86400}\right) = \boxed{5 \ m^2}$$

2\. b) $T_2 = T_{sat}$ @ 150 kPa = **111.35°C**

c)



adiabatic mixer

$$0 = \dot{m}_3 h_3 - \dot{m}_2 h_2 - \dot{m}_1 h_1$$

$$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 \,, \quad \dot{m}_2 = \dot{m}_3 - \dot{m}_1$$

$$0 = \dot{m}_3 h_3 - (\dot{m}_3 - \dot{m}_1) h_2 - \dot{m}_1 h_1$$

$$0 = \dot{m}_3 (h_3 - h_2) + \dot{m}_1 (h_2 - h_1)$$

$$0 = \dot{m}_3 \cancel{c_p} (T_3 - T_2) + \dot{m}_1 \cancel{c_p} (T_2 - T_1)$$

$$\dot{V}_3 = 5 \, \frac{L}{min} \cong 5 \, \frac{kg}{min}$$

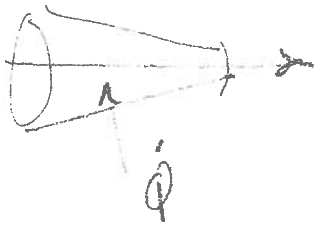
$$0 = 5 \, \frac{kg}{min} (40 - 15) + \dot{m}_1 (15 - 111.35)$$

$$\dot{m}_1 = \frac{125}{96.35} = \boxed{1.3 \, \frac{kg}{min} \text{ hot water}}$$

$$\dot{m}_2 = 5 - 1.3 = \boxed{3.7 \, \frac{kg}{min} \text{ cold water}}$$

3. air in nozzle

27°C
120 kPa
200 m/s
0.04 m²



60 kPa
500 m/s
27°C

1st Law $\quad \dot{Q} = \dot{m}\left(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2000}\right)$

$$\dot{m} = \rho_1 V_1 A_1 = \frac{P_1}{RT_1} V_1 A_1 = \frac{120\,(200)\,0.04}{0.287\,(300)} = 11.15\ \frac{kg}{s}$$

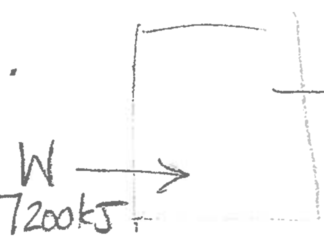
$$\dot{Q} = \dot{m}\left(C_p(T_2 - T_1) + \frac{V_2^2 - V_1^2}{2000}\right)$$

($C_p(T_2 - T_1) \to 0$)

a) $\dot{Q} = 11.15\ \frac{kg}{s}\left(\frac{500^2 - 200^2}{2000}\right) = $ **1,170 kW (heat input)**

b) $A_2 = \frac{\dot{m}}{\rho_2 V_2} = \frac{11.15\ kg/s}{\frac{60}{0.287(300)}\,(500)\ \frac{kg}{m^3}\frac{m}{s}} = $ **0.032 m²**

4.



$\dot{Q} = -1.5\,(3600)$ kJ

$$Q - W = \Delta U$$

$$\Delta U = +7{,}200\ kJ - 5400\ kJ = 1800\ kJ$$

$= $ **1.8 MJ** (6)

5. polytropic process

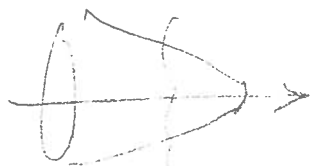
$$P_1 V_1^{n} = P_2 V_2^{n} \qquad \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{n}$$

$$\ln\left(\frac{100}{1000}\right) = n \ln\left(\frac{0.147}{1}\right), \quad n = 1.2$$

5. $$W_b = \frac{P_2V_2 - P_1V_1}{(1-n)} = \frac{1000(0.147) - 100(1)}{(1-1.2)}$$ (4)

$$\boxed{W_b = -235\text{ kJ}}$$ (d)

6.



1MPa
250°C
30 m/s

$\Delta h = -40$ kJ/kg

(2)

$$0 = \Delta h + \frac{V_2^2 - V_1^2}{2000}$$

$$40\frac{\text{kJ}}{\text{kg}} = \frac{V_2^2 - 30^2}{2000}$$

$$\boxed{V_2 = 284\text{ m/s}}$$ (d)

7. adiabatic pump (isentropic → adiabatic)

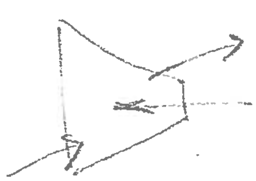
$P_1 = P_s$ @ 50°C = 12.4 kPa

$$-\dot{W}_p = \dot{m}v(P_2 - P_1)$$

$$-\dot{W}_p = 100\frac{\text{Mg}}{\text{hr}}\,10^3\frac{\text{kg}}{\text{Mg}}\left(\frac{1\text{hr}}{3600\text{s}}\right)\left(0.001012\frac{\text{m}^3}{\text{kg}}\right)(1000 - 12.4)\text{kPa}$$

$$\boxed{-\dot{W}_p = 27.8\text{ kW}}$$ (b)

8.



$\dot{W}$

2 atm
707°C

$\dot{m} = 10$ kg/s air

1 atm
37°C

$$-\dot{W} = \dot{m}(h_2 - h_1) = 10\frac{\text{kg}}{\text{s}}(1023 - 290.4)\frac{\text{kJ}}{\text{kg}}$$

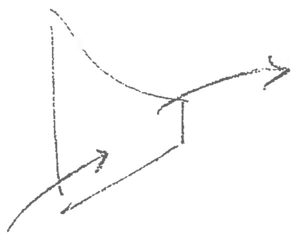
$$-\dot{W} = \boxed{7326\text{ kW}}$$ (d)

OR $$-\dot{W} = \dot{m}C_p(T_2 - T_1) = 10\frac{\text{kg}}{\text{s}}\left(1.1\frac{\text{kJ}}{\text{kgK}}\right)(980 - 310)) = 7370\text{ kW}$$ (d)

9. $PV^n = c$, $P_1 V_1^n = P_2 V_2^n$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n \quad \text{(a)}$$

10.



$$10\ m^3/min = \dot{V}_2 = \frac{\dot{m}}{\rho_2}$$

$$\dot{m} = \frac{P_2}{RT_2}\dot{V}_2 = \frac{1500\,(10/60)\ m^3/s}{0.287\,(273+130)}$$

$$= 2.16\ kg/s$$

$$\dot{m}q - \dot{W} = \dot{m}\left[c_p(T_2 - T_1)\right]$$

$$-\dot{W} = 2.16\ kg/s\left[1.008(130-40) + 90\right]$$

$$\dot{W} = -390\ kW \quad \text{(d)}$$

11. b) is best statement

$$\frac{dE_{cv}}{dt} = \dot{E}_{in} - \dot{E}_{out}$$

$$= \dot{Q} - \dot{W} + \sum_i \dot{m}_i e_i - \sum_e \dot{m}_e e_e$$