SOLUTIONS TO ASSIGNMENT

6.25/ <u>Given:</u> N_2 gas in 50 mm ϕ pipe

<u>State 1</u>: $T_1 = 15°C = 288\,K$ <u>State 2</u> $P_2 = 170\,kPa$

$P_1 = 200\,kPa$ $T_2 = T_1$

$\dot{m}_1 = 0.05\,kg/s$

<u>Find:</u> V_1 & V_2

<u>Assumptions</u>
1. Ideal Gas $\therefore\ Pv = RT$
2. Continuity $\therefore\ \dot{m} = \dot{m}_1 = \dot{m}_2$
3. Steady state $\frac{d\dot{m}}{dt} = 0$

<u>Sol'n:</u> <u>Area of pipe</u> $A = \frac{\pi}{4}(0.050)^2 = 0.001963\ m^2$

<u>inlet condition (state 1)</u>

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.2968)(288)}{200} = 0.04277\ m^3/kg$$

$$\therefore\ V_1 = \frac{\dot{m}v_1}{P_1} = \frac{0.05(0.04277)}{200}$$

$$\boxed{V_1 = 10.9\,m/s}$$

<u>exit condition (state 2)</u> $v_2 = \frac{RT_2}{P_2} = \frac{(0.2968)(288)}{170} = 0.5032\ m^3/kg$

$$\therefore\ V_2 = \frac{\dot{m}v_2}{P_2} = \frac{0.2968(0.5032)}{170}$$

$$\boxed{V_2 = 12.8\,m/s}$$

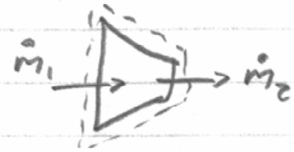
6.33/ Given: Air in Jet engine Nozzle. (Adiabatic)

State 1 (inlet to nozzle): $T_1 = 1000\,K$, $P_1 = 200\,kPa$, $V_1 = 30\,m/s$

State 2 (exit): $T_2 = 850\,K$, $P_2 = 90\,kPa$

Find: V_2.

Assumptions: C.V. is the nozzle.



1. No boundary work $\dot{W} = 0$
2. Adiabatic $\dot{Q} = 0$
3. Continuity $\dot{m} = \dot{m}_1 = \dot{m}_2$
3. conservation of energy + steady state.

$$\frac{dE}{dt} = 0 = \cancelto{0}{\dot{Q}} - \cancelto{0}{\dot{W}} + \sum \dot{m}_1\left(h_1 + \frac{V_1^2}{2} + gz_1\right) - \sum \dot{m}_2\left(h_2 + \frac{V_2^2}{2} + gz_2\right)$$

4. neglect potential energy

$$\therefore \dot{m}_1\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}_2\left(h_2 + \frac{V_2^2}{2}\right)$$

$$\text{or } h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

to find h_1 + h_2 → use table A.7.1.

$$\therefore V_2 = \sqrt{2\left(h_1 - h_2 + \frac{V_1^2}{2}\right)}$$

$$V_2 = \sqrt{\left[2\left(1046.22 - 877.4 + \frac{(30)^2}{2(1000)}\right)\right]1000}$$

$\uparrow$ to get proper units.

$$\boxed{V_2 = 581.8\ m/s}$$

6.49/ Given: Compressed Air in turbine (Adiabatic)

$$\dot{W}_{net,out} = 100\ W = 0.100\ kW$$

State 1: $P_1 = 400\ kPa$ State 2: $P_2 = 150\ kPa$
(inlet) $T_1 = 50°C = 323K$ (exit) $T_2 = -30°C = 243\ K$

Find: $\dot{m}$

Assumptions
1. Adiabatic $\dot{Q} = 0$
2. Low velocities ∴ neglect kinetic energy
3. neglect potential energy
4. continuity ∴ $\dot{m} = \dot{m}_1 = \dot{m}_2$
5. Ideal Gas ∴ get C_p from table A.5
6. conservation of energy + steady state

$$\therefore \frac{dE}{dt} = 0 = \cancelto{0}{\dot{Q}} - \dot{W} + \dot{m}h_1 - \dot{m}h_2$$

$$\dot{W} = \dot{m}(h_1 - h_2)$$

or $w = h_1 - h_2 = C_p(T_1 - T_2)$

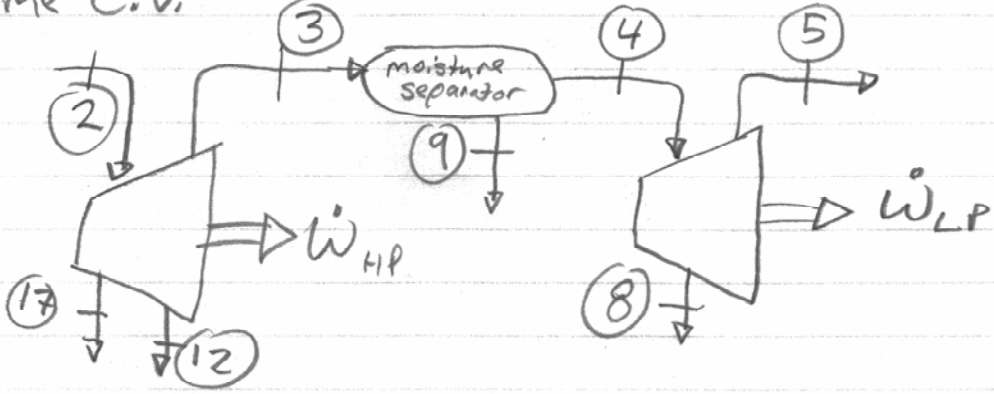
$$w = (1.004\ kJ/kg\,K)(323-243) = 80.3\ kJ/kg$$

$$\therefore \quad \dot{m} = \frac{\dot{W}}{w} = \frac{0.100}{80.3}$$

$$\boxed{\dot{m} = 0.00125\ kg/s}$$

(Steam)

6.102/ Consider only the following part of the system as the C.V.



a) Moisture Separator

Assume Steady State and Adiabatic and no work

from continuity $\dot{m}_3 = \dot{m}_4 + \dot{m}_9$

from conservation of energy: $\dot{m}_3 h_3 = \dot{m}_4 h_4 + \dot{m}_9 h_9$

Find: h_4 + X_4

$$h_4 = \frac{(62.874)(2517) - (4.662)(558)}{(58.212)}$$

$$\boxed{h_4 = 2673.9 \text{ kJ/kg}}$$

$$h_4 = h_f + X_4 h_{fg} = 566.18 + X_4 \cdot 2160.6$$

$$\therefore \boxed{X_4 = 0.9755}$$

b) LP turbine

Assume steady state + adiabatic

from continuity, $\dot{m}_4 = \dot{m}_5 + \dot{m}_8$

from conservation of energy: $\dot{m}_4 h_4 = \dot{m}_5 h_5 + \dot{m}_8 h_8 + \dot{W}_{LP}$

Find: $\dot{W}_{LP}$

$$\dot{W}_{LP} = (58.212)(2673.9) - (55.44)(2279) - (2.772)(2459)$$

$$\boxed{\dot{W}_{LP} = 22489\,kW = 22.489\,MW}$$

c) HP turbine

Assume Steady state + adiabatic

from continuity $\dot{m}_2 = \dot{m}_3 + \dot{m}_{17} + \dot{m}_{12}$

from conservation of energy:

$$\dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{m}_{12} h_{12} + \dot{m}_{17} h_{17} + \dot{W}_{HP}$$

Find $\dot{W}_{HP}$

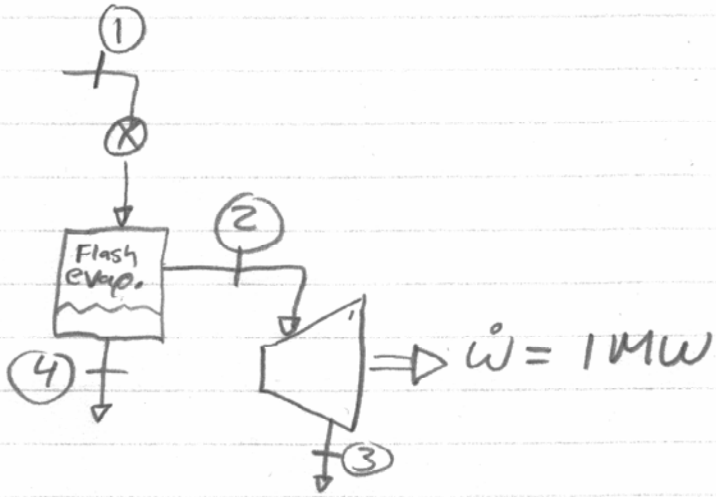
$$\dot{W}_{HP} = (75.6)(2765) - 62.874(2517) - 8.064(2517) - 4.662(2593)$$

$$\boxed{\dot{W}_{HP} = 18394\,kW = 18.394\,MW}$$

d) find efficency $\eta = \frac{(\dot{W}_{HP} + \dot{W}_{LP})}{\dot{Q}_{React.}} = \frac{(22.489 + 18.394)\,MW}{157\,MW.}$

$$\boxed{\eta = 0.26}$$

6.105/ Given: H_2O system



state 1: $P_1 = 1.5\ MPa$
$T_1 = 180°C$

state 2: $P_2 = 400\ kPa$
sat vapour $X_2 = 1$

state 3: $P_3 = 10\ kPa$
$X_3 = 0.90$

state 4: $P_4 = 400\ kPa$
sat liquid $X_4 = 0$

Find: $\dot{m}_1$

Soln: in flash evaporator → separation of phases
h = constant through throttling value.
$\therefore h_1 = h_f + X h_{fg}$ or $h_1 = h_4 + X(h_2 - h_4)$

$h_1 = 763.5\ kJ/kg$ from table B.1.3
$h_f = h_4 = 604.74\ kJ/kg$
$h_g = h_2 = 2738.6\ kJ/kg$

$\therefore X$ in flash evap. $= \dfrac{763.5 - 604.74}{2738.6 - 604.74} = 0.07439 = \dfrac{\dot{m}_2}{\dot{m}_1}$

or $\dot{m}_1 = \dfrac{\dot{m}_2}{0.07439}$.

Accross turbine, $\dot{W} = \dot{m}_2 (h_2 - h_3)$

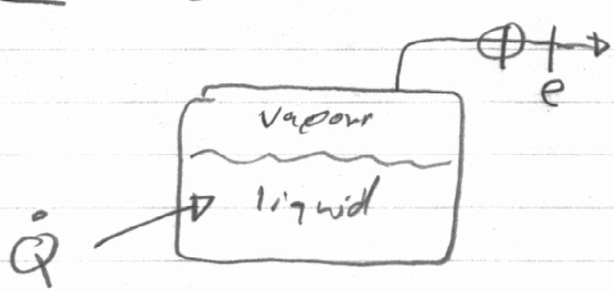
since $\dot{m}_2 = \dot{m}_3$ (from continuity) from table B.1.2,

$$h_3 = h_f + X h_{fg} = 191.83 + (0.9)(2392.8) = 2345.4 \text{ kJ/kg}$$

$$\therefore \dot{m}_2 = \frac{\dot{W}}{h_2 - h_3} = \frac{1000}{2738.6 - 2345.4} = 2.543 \text{ kg/s}$$

$$\therefore \dot{m}_1 = \frac{2.543}{0.07439}$$ $$\boxed{\dot{m}_1 = 34.19 \text{ kg/s} = 123075 \text{ kg/hr}}$$

6.117/ Given: H_2O in 200L tank



State 1: $P_1 = 100$ kPa
$X_1 = 0.01$

State 2: $P_2 = 2$ MPa

State 3: $P_3 = P_2$
$X_3 = 0.90$

Find: m_e, Q

Soln: C.V. is the tank.
Assume tank is rigid $\therefore$ no work, $\dot{W} = 0$

from continuity, $m_2 = m_1$

and $m_3 - m_1 = -m_e$

from conservation of energy, $\frac{dE}{dt} = \dot{Q} - \dot{m}_e h_3$

or,

$\Delta E = m_3 u_3 - m_1 u_1 = Q_{13} - m_e h_3$

State 1

From table B.1.2, $v_1 = v_f + x_1 v_{fg}$

$v_1 = 0.001043 + (0.01)(1.69296)$

$v_1 = 0.01797 \text{ m}^3/\text{kg}$

$u_1 = u_f + x u_{fg} = (417.33) + (0.01)(2088.72) = 438.22 \text{ kJ/kg}$

$m_1 = \frac{V}{v_1} = \frac{0.2 \text{ m}^3}{0.01797 \text{ m}^3/\text{kg}} = 11.13 \text{ kg}$

State 3 $v_3 = v_f + x v_{fg} = 0.001177 + (0.9)(0.09845) = 0.8978 \text{ m}^3/\text{kg}$

$u_3 = u_f + u_{fg} = 906.42 + (0.9)(1693.84) = 2430.88 \text{ kJ/kg}$

$m_3 = \frac{V}{v_3} = \frac{0.2 \text{ m}^3}{0.8978 \text{ m}^3/\text{kg}} = 2.23 \text{ kg}$

$\therefore \boxed{m_e = m_1 - m_3 = 11.13 - 2.23 = 8.90 \text{ kg}}$

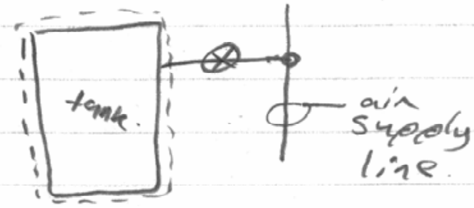
$h_3 = h_g$ at 2 MPa $= 2799.51 \text{ kJ/kg}$

$\therefore Q_{13} = m_3 u_3 - m_1 u_1 + m_e h_e$ (from 1st Law)

$Q_{13} = (2.23)(2430.88) - 11.13(438.22) + (8.90)(2799.51)$

$\boxed{Q_{13} = 25459 \text{ kJ} = 25.46 \text{ MJ}}$

6.111/ Given: Air in 25L tank.



state 1: $m_1 = 0$ (evacuated)
$P_1 = 0$

State 2: $P_2 = 600$ kPa

incomming air: $T_i = 20°C = 293K$
$P_i = 800$ kPa

Find: T_2

Sol'n C.V. is the tank.

Assume 1. tank is rigid ∴ no work, $\dot{W} = 0$
2 tank is adiabatic ∴ $\dot{Q} = 0$
3. continuity, $m_2 = m_i$
4. conservation of energy, $\frac{dE}{dt} = \cancel{\dot{Q}}^{0} - \cancel{\dot{W}}^{0} + m_i h_i$
(neglect KE + PE)

or, $\Delta E = \Delta U = m_2 u_2 = m_i h_i$ or $u_2 = h_i$
6. Ideal gas ∴ $Pv = RT$

from table A.7 $u_2 = h_i = 293.64$ kJ/kg
(interpolated for h at 293K)

then looking up $u_2 = 293$ in the same table, we can find T_2.

$T_2 = 410K$

∴ $m_2 = \frac{P_2 V}{R T_2} = \frac{600 \times 0.025}{0.287 \times 410} = 0.1275$ kg

Using specific heats to find T_2.

→ Assume constant specific heats

$$h_i = u_i + RT_i = u_2 \quad \therefore RT_i = u_2 - u_i$$

$$RT_i = C_{vo}(T_2 - T_i)$$

Work term associated with incomming fluid.

$$\therefore C_{vo}(T_2) = (C_{vo} + R)T_i = C_{po}T_i$$

$$\therefore T_2 = \left(\frac{C_{po}}{C_{vo}}\right)T_i = kT_i$$

for $T_i = 293 K$ + consts C_p + C_v.

$$T_2 = 1.40\,(293K)$$

$$\boxed{T_2 = 410.5\,K}$$