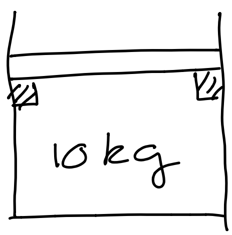
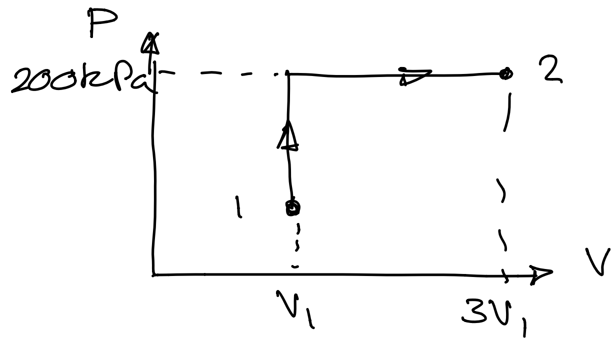
SOLUTION

CHE 260 MID-TERM 2017

1)





Energy Balance $\quad Q + W = \Delta U = m(u_2 - u_1)$

At 100kPa $\quad v_f = 0.001043\ m^3/kg \quad v_g = 1.6941\ m^3/kg$

$u_f = 417.40\ kJ/kg \quad u_g = 2505.6\ kJ/kg$

$u_1 = 417.40 + 0.5(2505.6 - 417.4) = 1461.5\ \frac{kJ}{kg}$

$v_1 = 0.001043 + 0.5(1.6941 - 0.001043) = 0.8476\ m^3/kg$

At state 2 $\quad P_2 = 200\ kPa$

$v_2 = 3v_1 = 2.5427\ m^3/kg.$

At 200kPa $\quad v_g = 0.8857\ m^3/kg$

$v_2 > v_g \Rightarrow$ Superheated vapour.

At 200kPa

	T	v	u
	800°	2.47550	3664.7
Interpolate →	829°	2.5427	3710.5
	900°	2.70656	3856.3

$\Rightarrow V_2 = m v_2 = 10 \times 2.5427$

$= 25.427\ m^3$

$$W_{12} = -P(V_2 - V_1)$$
$$= -200(25.427 - 8.475)$$
$$= -3390.4 \text{ kJ}$$

$$Q_{12} = m(u_2 - u_1) - W_{12}$$
$$= 10(3710.5 - 1461.5) + 3390.4$$
$$= 25880.4 \text{ kJ}$$

2) Final pressure

$$P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}} = 500\left(\frac{293.15}{373.15}\right)^{\frac{1.3}{0.3}} = 175.7 \text{ kPa}$$

$$w_{12} = \frac{P_2V_2 - P_1V_1}{n-1} = \frac{R(T_2 - T_1)}{n-1}$$

$$= \frac{0.2765\,(20-100)}{0.3} = -73.7 \text{ kJ/kg.}$$

$$q_{12} = C_v(T_2 - T_1) - w_{12}$$

$$= 1.49\,(20-100) + 73.7 = -45.5 \text{ kJ/kg}$$

ENTROPY CHANGE

$$s_2 - s_1 = C_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}.$$

$$= 1.766 \ln\frac{293.15}{373.15} - 0.2765 \ln\frac{175.7}{500}$$

$$= -0.1370 \text{ kJ/kgK.}$$

$$\Delta S_{surr} = \frac{-mq_{12}}{T_{surr}} = \frac{2\times 45.5}{293.15} = 0.3104 \text{ kJ/kg}$$

$$\Delta S_{gen} = \Delta S_{sys} + \Delta S_{surr}$$

$$= 2(-0.1370) + 0.3104$$

$$= 0.0364 \text{ kJ/K.}$$

3)

For compressor

$$\dot{W}_c = \dot{m}(h_2 - h_1) = \dot{m} C_p (T_2 - T_1)$$

$$\dot{W}_c = 10(620 - 295) = 3250 \text{ kW}$$

For turbine, at 3.5 MPa, 500°C

$$h_1 = 3451.7 \text{ kJ/kg}$$

At 10 kPa.

$$h_f = 191.81 \text{ kJ/kg}$$

$$h_{fg} = 2392.1 \text{ kJ/kg}$$

$$h_2 = h_f + x_2 h_{fg}$$

$$= 191.81 + 0.92 \times 2392.1$$

$$= 2392.5 \text{ kJ/kg}$$

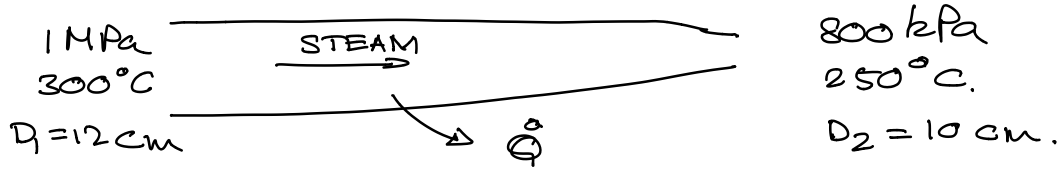
$$\dot{W}_T = \dot{m}(h_2 - h_1)$$

$$= 25(2392.5 - 3451.7)$$

$$= -26480 \text{ kJ/kg}$$

$$\frac{|\dot{W}_c|}{|\dot{W}_T|} = \frac{3250}{26480} = 12.3\%$$

4)



At 1 MPa, 300°C $\Big\}$ $v_1 = 0.25799$ m³/kg, $h_1 = 3051.6$ kJ/kg.

At 800 kPa, 250°C $\Big\}$ $h_2 = 2950.4$ kJ/kg.

a) $$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{\pi (0.12)^2}{4} \times \frac{2}{0.25799}$$

$$= 0.0877 \text{ kg/s}$$

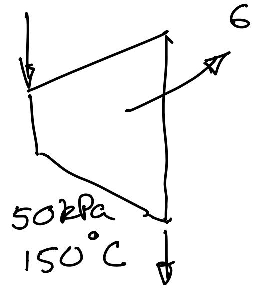
b) $$\dot{Q} = \dot{m}(h_2 - h_1)$$

$$= 0.0877 \; (2950.4 - 3051.6)$$

$$= -8.88 \text{ kJ/s}$$

The pipe loses 8.88 kW of heat

5)



3MPa, 600°C: $h_1 = 3682.8$ kJ/kg, $s_1 = 7.5103$ kJ/kgK

50 kPa, 150°C: $h_2 = 2780.2$ kJ/kg, $s_2 = 7.9413$ kJ/kgK

a) $$\dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$-6000 = \dot{m}\left[(2780.2 - 3682.8) + \frac{(140)^2 - (80)^2}{2 \times 1000}\right]$$

$$\dot{m} = 6.696 \text{ kg/s}$$

b) For isentropic process $s_{2s} = s_1 = 7.5103 \frac{kJ}{kgK}$

At 50 kPa $s_f = 1.0912$ kJ/kgK, $h_f = 340.54$ kJ/kg

$s_g = 7.5931$ kJ/kgK, $h_g = 2645.2$ kJ/kg

$$x_{2s} = \frac{s_{2s} - s_f}{s_g - s_f} = \frac{7.5103 - 1.0912}{7.5931 - 1.0912} = .9873$$

$$h_{2s} = h_f + x_{2s}(h_g - h_f)$$

$$= 340.54 + 0.9873\,(2645.2 - 340.54) = 2615.9 \frac{kJ}{kg}$$

$$\dot{W}_s = \dot{m}\left[(h_{2s} - h_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$= 6.696\left[(2615.9 - 3682.8) + \frac{140^2 - 80^2}{2 \times 1000}\right]$$

$$\dot{W}_s = -7099.8 \text{ kW}$$

$$\eta_t = \frac{\dot{W}_a}{\dot{W}_s} = \frac{6000 \text{ kW}}{7099.8 \text{ kW}} = 0.85$$