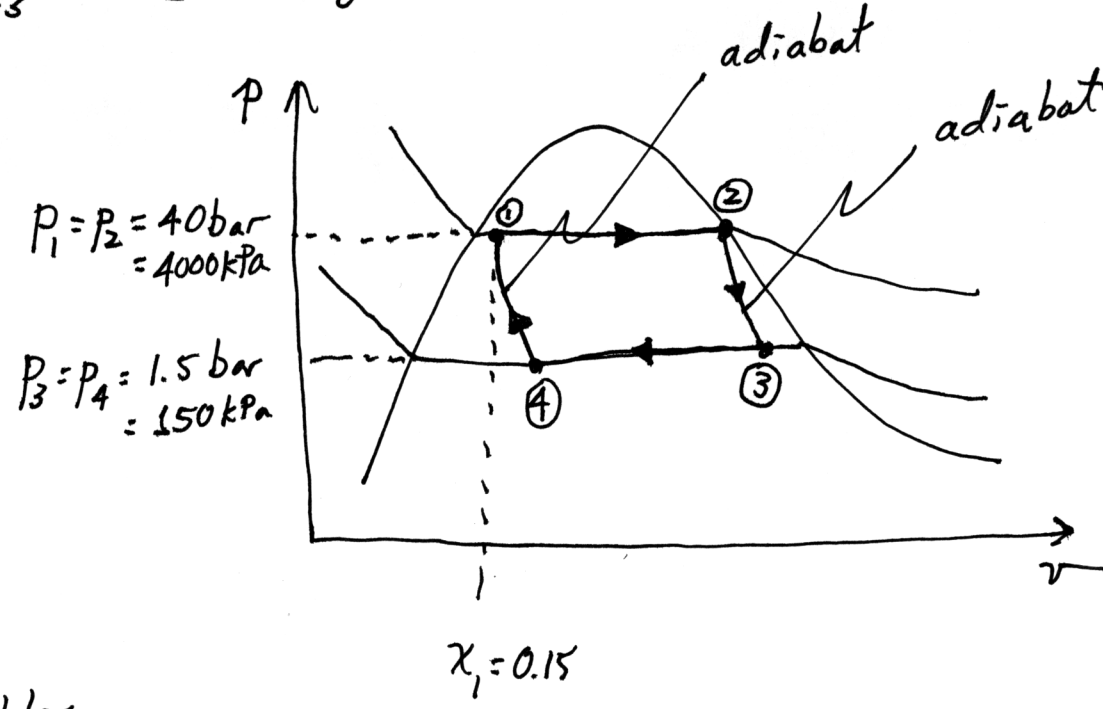
5.61 Given Carnot power cycle, working fluid is water, 2kg

$w_{2-3} = 491.5\ kJ/kg$



From Steam Tables

$P_1 = P_2 = 40\ bar \quad T_1 = T_2 = 250.4°C = 523.4K$

$P_3 = P_4 = 1.5 bar \quad T_3 = T_4 = 111.4°C = 384.4K$

$$v_1 = (1-x_1)v_f + x_1 v_g = (1-0.15)\left(1.25\times10^{-3}\frac{m^3}{kg}\right) + 0.15\left(.04978\frac{m^3}{kg}\right)$$

$$v_1 = 0.00853\ m^3/kg$$

$$v_2 = v_g = 0.04978\ m^3/kg$$

similarly, $h_1 = 1344\ kJ/kg$

$h_2 = 2801\ kJ/kg$

(b)

We know $\boxed{Q_{4-1} = 0}$ $\boxed{Q_{2-3} = 0}$

$$W_{2-3} = m w_{2-3} = (2kg)(491.5\ kJ/kg) \qquad \boxed{W_{2-3} = 983\ kJ}$$

$$W_{1-2} = m\int_1^2 p\,dv = mp(v_2 - v_1) = (2kg)(4000kPa)(.04978\tfrac{m^3}{kg} - .00853\tfrac{m^3}{kg}$$

$$\boxed{W_{1-2} = 330\ kJ}$$

5.61, cont'd | First Law $\Delta E = Q - W$; assuming $\Delta KE = \Delta PE = 0$

$$\Delta U = Q - W \Rightarrow \quad \Delta u = q - w$$

Process 1-2 $\quad u_2 - u_1 = q_{1-2} - w_{1-2} = q_{1-2} - p(v_2 - v_1)$

$$u_2 + p_2 v_2 - u_1 - p_1 v_1 = q_{1-2}$$

$$h_2 - h_1 = q_{1-2}$$

$$Q_{1-2} = m(h_2 - h_1) = (2kg)\left(2801 \frac{kJ}{kg} - 1344\ kJ/kg\right)$$

$$\boxed{Q_{1-2} = 2914\ kJ}$$

Using Eq (5.6) $\quad \left|\frac{Q_C}{Q_H}\right|_{\substack{rev \\ cycle}} = \frac{T_C}{T_H}$ — a Carnot cycle is a reversible cycle

$$\left|\frac{Q_{1-2}}{Q_{3-4}}\right| = \frac{384.4K}{523.4K}$$

$$\boxed{Q_{3-4} = -2138kJ}$$

also $\quad Q_{3-4} = m(h_3 - h_4)$

process 2-3 $\quad \Delta u = q - w \quad u_3 - u_2 = q_{2-3} - w_{2-3}$

$$u_3 - u_2 = -491.5\ kJ/kg \qquad u_2 = 2602.3\ kJ/kg$$

$$u_3 = 2110.8\ kJ/kg$$

$$u_3 = (1 - x_3)u_f + x_3 u_g$$

$$2110.8\ kJ/kg = (1 - x_3)(466.94\ kJ/kg) + x_3(2519.7\ kJ/kg)$$

$$\boxed{x_3 = 0.80}$$

$$h_3 = (1 - .8)(467.11\ kJ/kg) + (0.8)(2693.6\ kJ/kg)$$

$$h_3 = 2248.3\ kJ/kg$$

5.61 cont'd

$$Q_{3-4} = -2138\,kJ = (2kg)(2248.3\tfrac{kJ}{kg} - h_4)$$

$$h_4 = 1179.3\ kJ/kg$$

Now get x_4

$$h_4 = (1-x_4)h_f + x_4 h_g \Rightarrow \underline{x_4 = 0.32}$$

Knowing x_3, x_4, get v_3, v_4

$$v_3 = 0.927\ m^3/kg$$

$$v_4 = 0.372\ m^3/kg$$

(W1-2) $$W_{3-4} = m\int_3^4 p\,dv = mp(v_4 - v_3)$$

$$= (2kg)(150kPa)(0.372\tfrac{m^3}{kg} - 0.927\tfrac{m^3}{kg})$$

$$\boxed{W_{3-4} = -166.5\,kJ}$$

Finally, process 4-1

~~Since~~ Since $W_{cycle} = Q_{cycle}$

$$W_{1-2} + W_{2-3} + W_{3-4} + W_{4-1} = Q_{1-2} + \cancel{Q_{2-3}}^{\,0} + Q_{3-4} + \cancel{Q_{4-1}}$$

$$330kJ + 983kJ - 166.5kJ + W_{4-1} = 2914kJ - 2138kJ$$

$$\boxed{W_{4-1} = -370.5\,kJ}$$

(c) $\eta = ?$ Carnot cycle is reversible, so $\eta = 1 - \frac{T_c}{T_H}$

$$\boxed{\eta = 0.266}$$