Example

Two kg of saturated steam vapor is contained in a piston cylinder at 200 kPa. It undergoes a constant pressure process until the quality is 0.5. The surroundings are at 101 kPa and 300 K.

(a) Find the work out of the steam for this process.
(b) Find the useful work out of the steam for this process.
(c) What is the maximum amount of useful work that can be extracted from the steam
   1. at its initial state?
   2. at its final state?
   3. between the two states?
(d) How do your answers to (b) and (c) compare? What does that mean?
(e) Calculate the heat transfer in or out of the system and the entropy generation using a good ole ConApps approach. How does $T_0s_{gen}$ compare to part (d)?

\[ W_{out,12} = \int p\,dv = mp_1(v_2 - v_1) \]
\[ v_1 = v(P_1, x=1) = \]
\[ v_2 = v(P_2 = P_{12}, x=0.5) = \]
\[ W_{out,12} = -177 \text{ kJ} \]
\[ W_{use,12} = W_{out,12} - p_o(v_2 - v_1) \]
\[ = W_{out,12} - mp_o(v_2 - v_1) \]
\[ = -87.7 \text{ kJ} \]

ATMOSPHERE DOES WORK ON SYSTEM
(1) \( W_{\text{max,use, out, } 1 \rightarrow 0} = A_1 \)
\[ = ma_1 = m \left[ (u_1 - u_0) + p_0 (v_1 - v_0) - T_0 \delta_e - \Delta_0 \right] \]

IN STATE (1)

\( u \) stuff if it were \( T_0, p_0 \)

( NOT \( u \) of environment)

\( u_1 = u (P = p_1, x = 1) \)
\[ = 2529 \text{ KJ/kg} \]

\( u_0 = u (P = p_0 = 101 \text{ KPa}, T = T_0 = 300 \text{ K}) \)
\[ = 112.5 \text{ KJ/kg} \]

\( v_1, v_0, p_1, \Delta_0 \) FOUND IN SIMILAR MANNER

\[ \ldots \quad A_1 = \ldots = 971.5 \text{ KJ} \]

(2) \( W_{\text{max,use, 2 \rightarrow 0}} = A_2 \)
\[ = ma_2 = m \left[ (u_2 - u_0) + p_0 (v_2 - v_0) - T_0 \delta_e - \Delta_2 \right] \]
\[ = \ldots = 537 \text{ KJ} \]

(3) \( W_{\text{max, out, use, 1 \rightarrow 2}} = A_1 - A_2 = \ldots \)
\[ \text{DECREASE IN A} \]
\[ = (971.5 - 537) \text{ KJ} = 435 \text{ KJ} \]
(d) We could have gotten work out of the system, instead we put work in. I really should have done things reversibly.

But wait! The steam was compressed. How could I have gotten work out, then?

Cons. of energy, closed system, finite time

\[ E_2 - E_1 = Q_{in,12} - W_{out,12} \]

No KE, PE

\[ U_2 - U_1 = Q_{in,12} - W_{out,12} \]

\[ Q_{in,12} = U_2 - U_1 + W_{out,12} = m(c_u_2 - c_u_1) + W_{out,12} \]

\[ U_1 = U(P=P_1, \xi=1) = 2529 \text{ kJ/kg} \]

\[ U_2 = U(P=P_2=P_1, \xi=0.5) = 1517 \text{ kJ/kg} \]

\[ Q_{in,12} = \ldots = -2202 \text{ kJ} \Rightarrow W_{out,12} = 2202 \text{ kJ} \]

This heat transfer out could have been used to produce work out.
Account of $S_1$, closed sys, finite time

$$ (S_2 - S_1)_\text{sys} = \frac{Q_{in12}}{T_0} + S_{gen} $$

$$ m(A_2 - A_1) = -\frac{Q_{out12}}{T_0} + S_{gen} $$

$$ S_{gen} = m(A_2 - A_1) + \frac{Q_{out12}}{T_0} $$

$$ = (2 \text{ kg})(4.329 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} - 7.127 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}) + \frac{2202 \text{kJ}}{300 \text{ K}} $$

$$ = 1.74 \text{ KJ/K} $$

$$ I_{12} = T_0 S_{gen} = (300 \text{ K})(1.74 \text{ KJ/K}) $$

$$ = 523 \text{ KJ} $$

**COMPARE TO**

$$ W_{out12} - W_{out12}^{\text{max,use}} = 435 \text{ KJ} - (-87.7 \text{ KJ}) $$

$$ = 523 \text{ KJ} $$

**FROM PARTS (b)**

(c)