WEEK 9 SOL'NS

8.43 / Given: water in insulated piston/cyl.

State 1: $m_1 = 0.1\,kg$ State 2: $P_2 = 1.2\,MPa$

$T_1 = 100°C$

$x = 0.90$

Find: W_{12}

CV. cylinder

Soln: Assume 1. Adiabatic $Q_{12} = 0$

2. Reversible Process

3. Neglect ke + pe

4. Continuity $m_1 = m_2 = m$

5. 1st Law:

$\Delta E \approx \Delta U = Q - W$

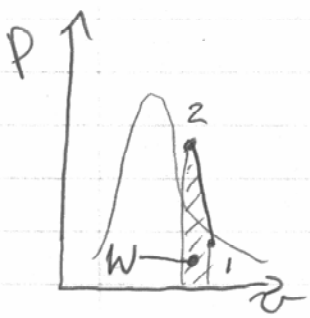
$W_{12} = -m(u_2 - u_1)$

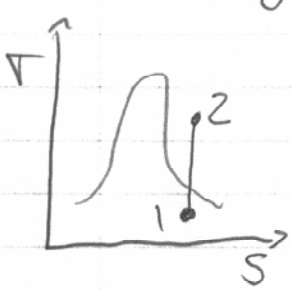
6. 2nd Law:

$dS = \int \frac{dQ}{T} = 0$

$m(s_2 - s_1) = \int \frac{dQ}{T} = 0$

$\therefore s_2 = s_1$





State 1: from table B.1.1

$s_1 = s_f + x s_{fg} = 1.3068 + 0.9(6.048)$

$s_1 = 6.75\ kJ/kg\,K$

$u_1 = u_f + x u_{fg} = 418.91 + 0.9(2087.58)$

$u_1 = 2297.7\ kJ/kg$

State 2 from table B.1.3. (from P_2, s_2)

$\left.\begin{array}{l} T_2 = 232.3°C \\ u_2 = 2672.9 \end{array}\right\}$ By interpolation

$\therefore W_{12} = -(0.1\,kg)(2672.9 - 2297.7) \Rightarrow \boxed{W_{12} = -37.5\,kJ}$

8.47/ <u>Given</u>: Ammonia in piston/cyl.

<u>State 1</u>: $m_1 = 2\ kg$
$T_1 = 50°C = 323\ K$
$P_1 = 100\ kPa$

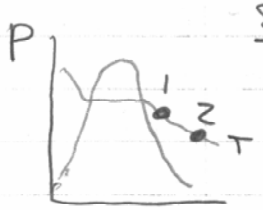
<u>State 2</u>: $P_2 = 1000\ kPa$
$T_2 = T_1$

<u>Process</u>: Reversible.

<u>Find</u>: Q_{12} and W_{12}

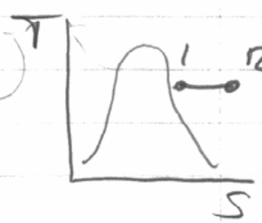
<u>Soln</u>: C.V. cylinder

<u>Assume</u>:
1. Reversible
2. neglect ke + pe
3. continuity $m_1 = m_2 = m$
4. 1st Law:
$\Delta E \approx \Delta U = Q_{12} - W_{12} = m(u_2 - u_1)$
5. 2nd Law
$dS = \int \frac{dQ}{T} = m(s_2 - s_1)$



<u>State 1</u> from table B.2.2
$v_1 = 1.5658\ m^3/kg$ $u_1 = 1424.7\ kJ/kg$
$s_1 = 6.4943\ kJ/kg\,K$

<u>State 2</u> from table B.2.2
$v_2 = 0.1450\ m^3/kg$ $u_2 = 1391.3\ kJ/kg$
$s_2 = 5.2654\ kJ/kg\,K$



from 2nd Law $Q_{12} = mT(s_2 - s_1) = 2(323)(5.2654 - 6.4943)$

$$\boxed{Q_{12} = -794.2\ kJ}$$

from 1st Law $W_{12} = Q_{12} - m(u_2 - u_1) = -794.24 - 2(1391.3 - 1424.62)$

$$\boxed{W_{12} = -727.6\ kJ}$$

8.59 / **Given**: Steam in rigid, insulated tank (Transient Process)
Overall process: irreversible
but steam remaining in tank goes through adiabatic + Reversible expansion (inside the tank)

State 1 $P_1 = 3\ MPa$ State 2 $X_2 = 1$
$T_1 = 400°C$

Find: fraction of steam that escapes, $\frac{m_e}{m_1}$

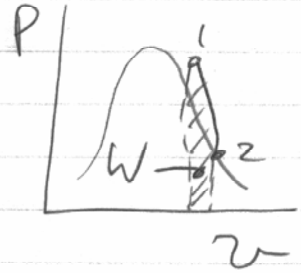
Soln: CV, steam inside tank
Assumptions
1. Reversible
2. Adiabatic $Q_{12} = 0$
3. Continuity $m_e = m_1 - m_2$
4. 1st Law:
$\Delta E \approx \Delta U = Q_{12} - W_{12} = m(u_2 - u_1)$
5. 2nd Law
$\frac{dS}{dt} = \int \frac{dQ}{T}$ (for reversible process)
$m(s_2 - s_1) = 0 \quad \therefore s_2 = s_1$

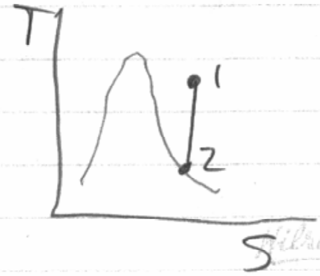
$s_1 = s_2 = 6.9212$ from P_1, T_1 in super heated tables

$\therefore T_2 = 141°C$ from s_2, X_2 in table B.1.1

$\therefore \frac{m_e}{m_1} = \frac{m_1 - m_2}{m_1} = 1 - \frac{m_2}{m_1} = 1 - \frac{v_2}{v_1} = 1 - \frac{0.09936}{0.4972}$

$\boxed{\frac{m_e}{m_1} = 0.80}$





8.60 **Given:** water in piston/cyl.

State 1: $m_1 = 2\,kg$
$T_1 = 200°C$
$P_1 = 10\,MPa$

State 2: $P_2 = 200\,kPa$
$T_2 = T_1$

Ambient: $T_0 = 200°C$

Process: isothermal $T_2 = T_1$

Find: Q_{12} + W_{12}

Sol'n C.V. water

Assume: 1. continuity $m_1 = m_2 = m$
2. neglect ke + pe
3. reversible process
4. 1st Law: $\Delta E \approx \Delta U = Q_{12} - W_{12} = m(u_2 - u_1)$
5. 2nd Law: $dS = \int \frac{dQ}{T}$

$$mT(s_2 - s_1) = Q_{12}$$

State 1: table B.1.4 ⇒ (compressed liquid table)
$v_1 = 0.001148\,m^3/kg$
$u_1 = 844.49\,kJ/kg$
$s_1 = 2.3178\,kJ/kg\,K$

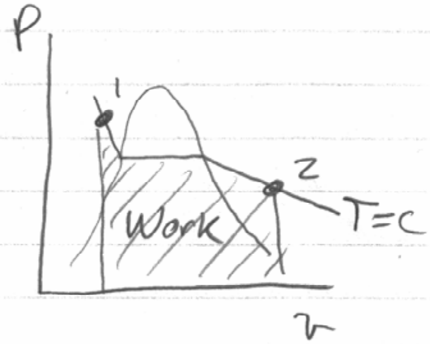
$$V_1 = m v_1 = (2\,kg)(0.001148\,m^3/kg) = 0.0023\,m^3$$

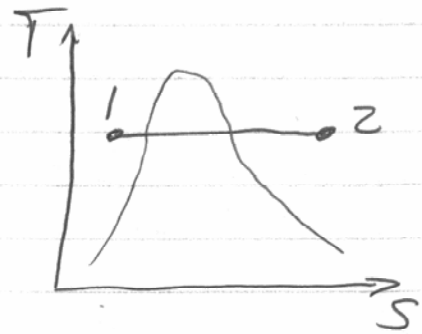
State 2: table B.1.3 ⇒ (superheated)
$v_2 = 1.08034\,m^3/kg$ $u_2 = 2654.4\,kJ/kg$
$s_2 = 7.5066\,kJ/kg\,K$

$$V_2 = m v_2 = (2\,kg)(1.08034\,m^3/kg) = 2.1607\,m^3$$

8.60 cont...

process





from 2nd Law

$$Q_{12} = mT(s_2 - s_1) = 2(473)(7.5066 - 2.3178)$$

$$\boxed{Q_{12} = 4910 \text{ kJ}}$$

from 1st Law $W_{12} = Q_{12} - m(u_2 - u_1)$

$$\boxed{W_{12} = 1290.3 \text{ kJ}}$$

8.126/ Given: H_2O in insulated cyl/piston

State 1: $V_1 = 0.15 m^3$ State 2: ?

$P_1 = 400$ kPa

$T_1 = 200°C$

Process: adiabatic, $Q_{12} = 0$, $W_{12} = 30$ kJ

Find: if state 2 is in two-phase region

Sol'n C.V. H_2O

Assume 1. Continuity $m_1 = m_2 = m$

2. Reversible process

8.126 cont....

3. 1st Law: $\Delta E \approx \Delta U = m(u_2 - u_1) = Q_{12} - W_{12}$

$$W_{12} = -m(u_2 - u_1)$$

4. 2nd Law: $dS = \int \frac{dQ}{T}$

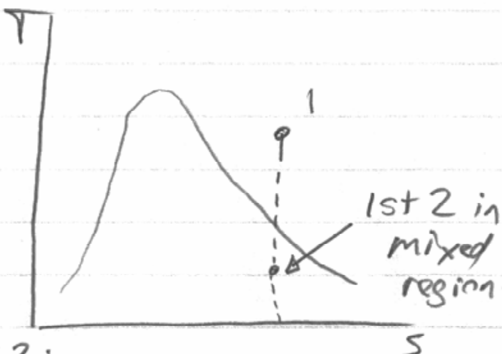
$$m(s_2 - s_1) = 0 \Rightarrow s_2 = s_1$$

State 1: from table B.1.3 (Superheated)

for $T_1, P_1 \Rightarrow v_1 = 0.5342$ m³/kg $u_1 = 2646.8$ kJ/kg

$s_1 = 7.1706$ kJ/kg K $= s_2$

$$m = \frac{V_1}{v_1} = \frac{0.15}{0.5342} = 0.2808 \text{ kg}$$



State 2:

from 1st Law: $u_2 = u_1 - \frac{W_{12}}{m} = 2646.8 - \frac{30}{0.2808}$

$$u_2 = 2540 \text{ kJ/kg}$$

from table B.1.1, if $u_2 = u_g$

$s_g = 7.0259$

$$s_g < s_2 \therefore u_2 \neq u_g$$

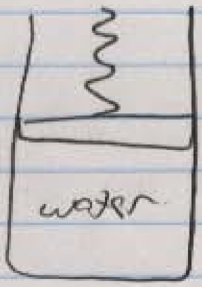
State 2 must be in Super heated region

Given: water in piston/cyl.

8.132 | State 1: $m_1 = 3\,kg$ State 2: $T_2 = 20°C$

$P_1 = 500\,kPa$

$T_1 = 600°C$



piston $A = 0.1\,m^2$

spring $K = 10\,kN/m$

Find: ΔS_{gen}

Soln: Assume 1. continuity: $m_1 = m_2 = m$

2. 1st Law: $\Delta E \approx \Delta U = Q_{12} - W_{12} = m(u_2 - u_1)$

3. 2nd Law:

$$dS = \frac{dQ}{T} + dS_{gen}$$

$$\text{or, } \Delta S_{gen} = m(s_2 - s_1) - \frac{Q_{12}}{T}$$

State 1

from table B.1.3 $\Rightarrow$ $v_1 = 0.8041$

$u_1 = 3299.6$

$s_1 = 7.3522$

State 2: from force balance at piston

$$P = P_1 + \left(\frac{k_s}{A^2}\right)(V - V_1)$$

since $\Sigma F_y = 0 = P_1 A - P_o A - k_s x_1$ at state 1

or $0 = P_1 A - P_o A - \frac{k_s V_1}{A}$

and $\Sigma F_y = 0 = PA - P_o A - \frac{k_s V}{A}$ at any point

$\therefore$ $P_1 A - P_o A - \frac{k V_1}{A} = PA - P_o A - \frac{k_s V}{A}$

or $P = P_1 + \left(\frac{K_s}{A^2}\right)(V - V_1)$

- Assume state two is in two phase region.

$\therefore\ P_2 = P_{sat}@(T_2) = 2.339\ kPa$

$\therefore\ v_2 = v_1 + \dfrac{(P_2 - P_1)A^2}{mK}$

$v_2 = 0.8041 + \dfrac{(2.339 - 500)(0.01)}{3(10)} = 0.6382$

$v_2 = v_f + x_2 v_{fg}$ yes, in two phase region

$\therefore\ x_2 = \dfrac{(0.6382 - 0.001002)}{57.7887} = 0.011$

$\therefore\ u_2 = 109.46\ ,\ s_2 = 0.3887$

~~from first Law~~

Work: $W_{12} = P_{avg} \cdot m(v_2 - v_1) = \frac{1}{2}(500 + 2.339)3(0.6382 - 0.8041)$

$W_{12} = -125\ kJ$

from ~~Second~~ first Law

$Q_{12} = m(u_2 - u_1) + W_{12} = 3(109.46 - 3299.6) - 125$

$Q_{12} = -9695.4\ kJ$

from Second Law

$\Delta S_{gen} = m(s_2 - s_1) - \dfrac{Q_{12}}{T_{room}}$

$\Delta S_{gen} = (3)(0.3887 - 7.3522) + \dfrac{9695.4}{293.15}$

$\boxed{\Delta S_{gen} = 12.18\ kJ/K}$

Hilroy

8.135/ <u>Given</u>: air in piston/cyl.

<u>State 1</u>: $P_1 = 500\,kPa$
$T_1 = 200°C = 473K$
$V_1 = 10L = 0.01m^3$

<u>state 2</u>: $P_2 = 150\,kPa$
$V_2 = 25L = 0.025m^3$

<u>Ambient</u>: $T_0 = 20°C = 293K$

process
~~Soln~~: 70% of work is reversible, adiabatic

Find: a) W_{12} and b) process is ~~if its~~ possible

<u>Soln</u>: C.V. Air, $R = 0.287\,kJ/kg\,K$, $C_p = 1.004\,kJ/kg\,K$
$C_v = 0.717\,kJ/kg\,K$

<u>State 1</u>: $m_1 = \frac{V_1}{v_1} = \frac{P_1 V_1}{R T_1}$ (assume Ideal Gas)

$m_1 = 0.0368\,kg$

Process ~~stated~~: isentropic efficiency of process $\eta_s = 0.70$
(actual work is 70% of isentropic work)

a) Assume reversible and adiabatic process
∴ from second law

$$dS = \frac{dQ}{T} \quad \text{or} \quad m(s_{2s} - s_1) = 0$$

$$\therefore s_{2s} = s_1$$

for a polytropic process, $PV^n = \text{constant}$.
and has the relation,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1} \Rightarrow \therefore T_{2s} = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

Hilroy

$n = k$ for an ~~isothermal~~ isentropic proces (p. 279 in thermo book)

for a reversible process,

$$T_{2s} = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 473\left(\frac{150}{500}\right) = 335\ K$$

from first Law: $Q_{12} = m(u_{2s} - u_1) + W_{12}$

$Q_{12} = 0$

Assume constant specific heats (ideal gas)

$$W_{12} = mC_v(T_1 - T_{2s}) = 3.63\ kJ$$

$\therefore W_{12\,(actual)} = \eta W_{12} = (0.7)(3.63)$

$$\boxed{W_{12\,(actual)} = 2.54\ kJ}$$

b) from Ideal gas law: $T_2 = T_1 \dfrac{P_2 V_2}{P_1 V_1} = 354.9\ k$

1st Law: $Q_{12} = mC_v(T_{2(actual)} - T_1) + W_{12(actual)}$

$Q_{12} = -0.58\ kJ$.

2nd Law: $\Delta S_{total} = m(s_2 - s_1) - \dfrac{Q_{cv}}{T_0}$, $Q_{cv} = Q_{12\,(actual)}$

$$s_2 - s_1 = C_p \ln\frac{T_2}{T_1} - R \ln\frac{P_2}{P_1} = 0.0569\ kJ/kg\,K$$

$$\Delta S_{total} = 0.00406\ kJ/K \geq 0$$

$\therefore$ Process is possible.

Hilroy