MAE91 Summer 2004 – Quiz 3
Dr. H. Susan Zhou

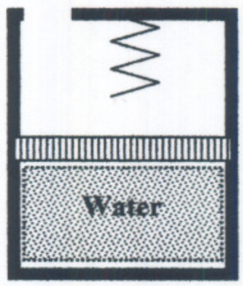
5/10

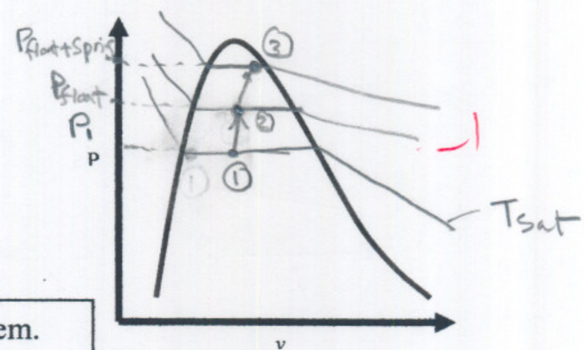
Closed book and notes – 20 minutes

Name: NASSER ABBASI
ID: ____________________

For each of the following processes draw a P-v and T-v diagrams. If there is a stop in the problem, assume that the process hits the stop and continues. Diagrams all show initial or ambient state. **(1 point per diagram)**

1)

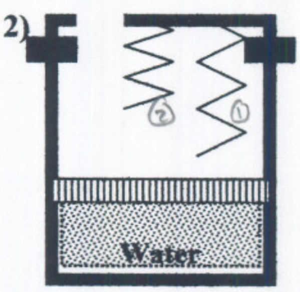


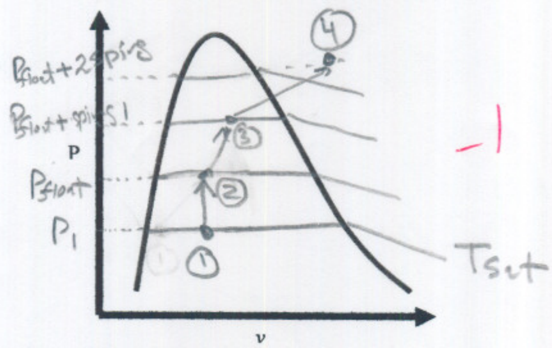


-1

Heat is added to the system.
x is always defined.

2)

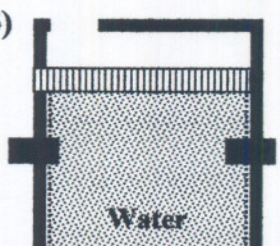


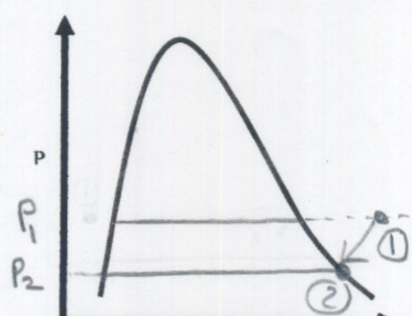


-1

Heat is added to the system.
Springs constants are the same.
x_1 defined, x_2 undefined

3)

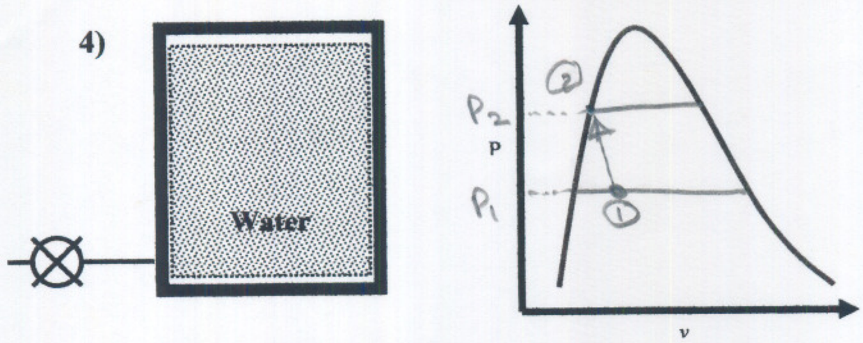




-1

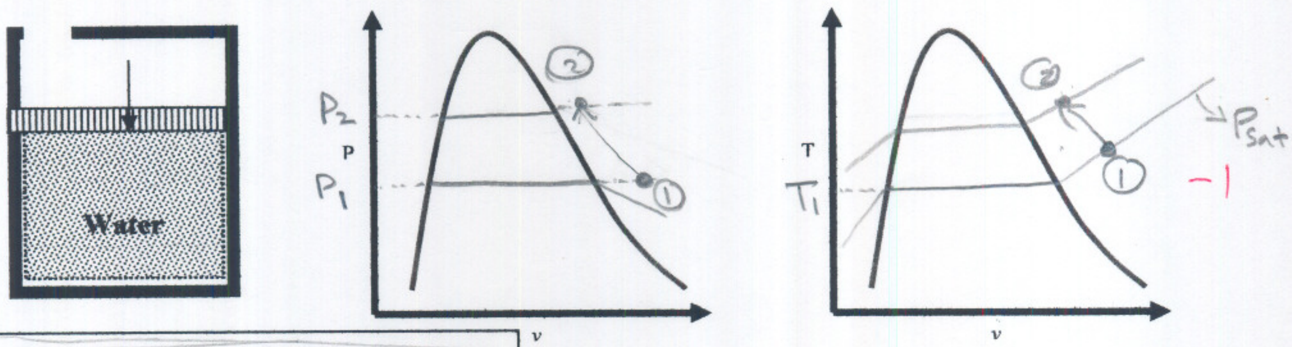
Heat leaves the system.
x_1 undefined, $x_2 = 1$

4)



Mass is added to the system.
Process is adiabatic. no Q.
x_1 defined, $x_2 = 0$

5)

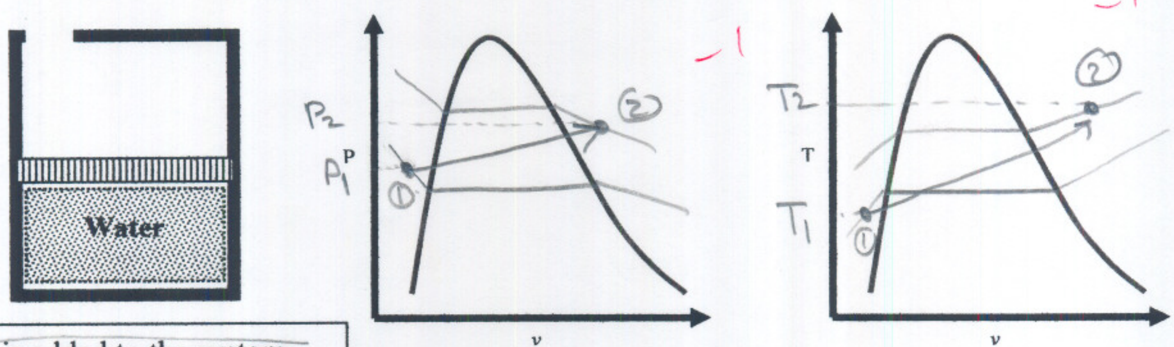


−1

Force added which pushes piston down.
Cylinder is refrigerated to a constant T.
x is always undefined and greater than 1.

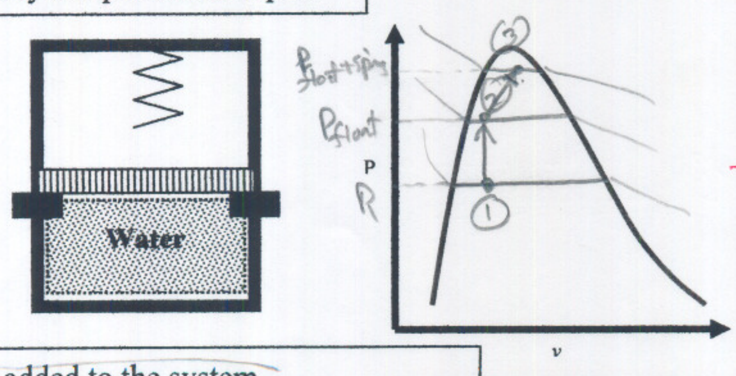
6)

−1 −1



Heat is added to the system.
Initially a compressed liquid.
Finally a superheated vapor.

7)

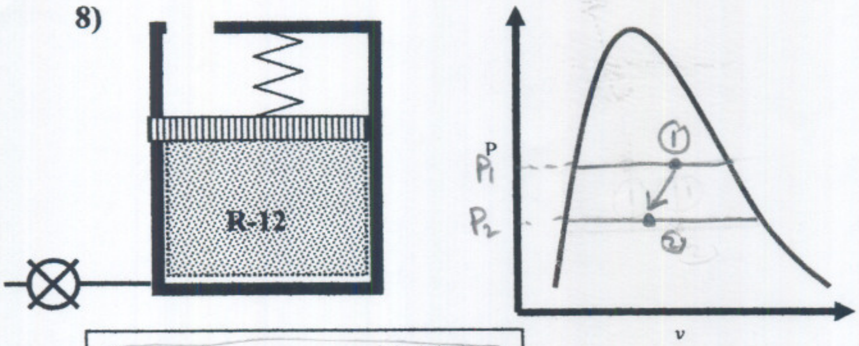


−1

so, if in liquid-vapor state, as more heat is added, averge density of liquid-vapor remain constant, but pressure increase

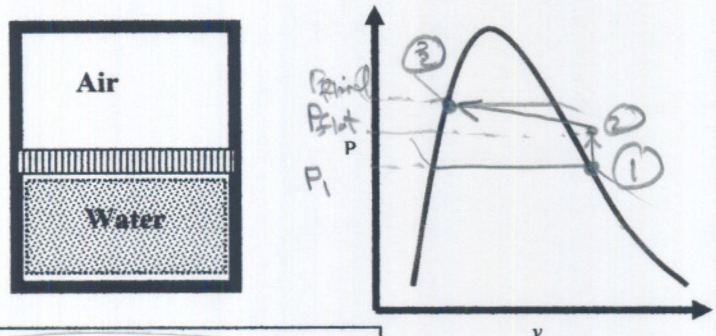
Heat is added to the system.
x is always defined. $P_1 < P_{float}$
P_{float} is the pressure needed to float piston

8)



Spring is compressed initially.
All mass leaves the system.
Initial quality is defined.

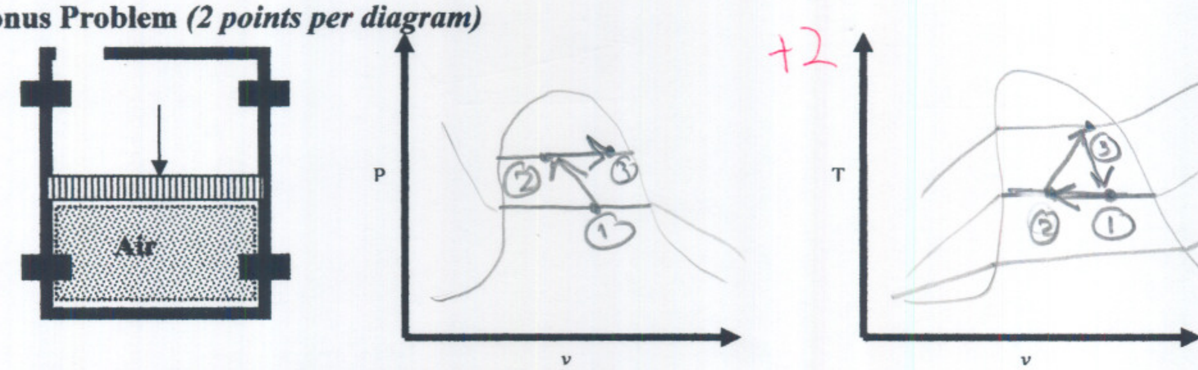
9)



Heat is added to the **air**.
C.V. is water.
Water is insulated.
$x_1 = 1, x_2 = 0$

Bonus Problem ***(2 points per diagram)***

+2



Multi-Stage Process

- Piston is pushed down to bottom stop while maintaining constant T.
- When piston reaches bottom stop force ceases and LARGE amount of heat is added to system.
- Pressure is now greater than initial pressure and pressure after compression.
- Piston then cools back to ambient conditions.

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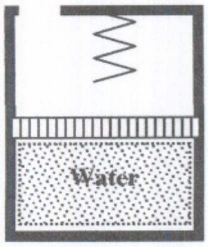
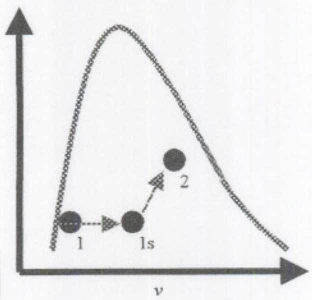
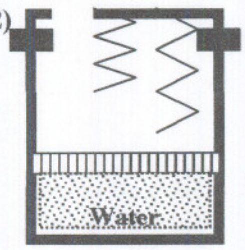
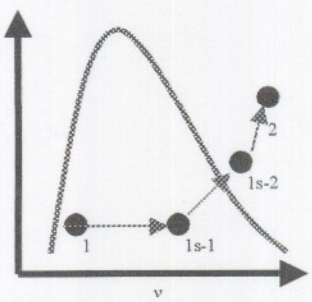




Heat is added to the system.
x is always defined.

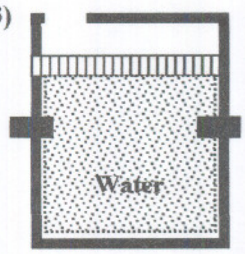
2)

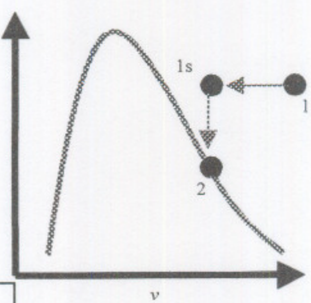




Heat is added to the system.
Springs constants are the same.
x_1 defined, x_2 undefined

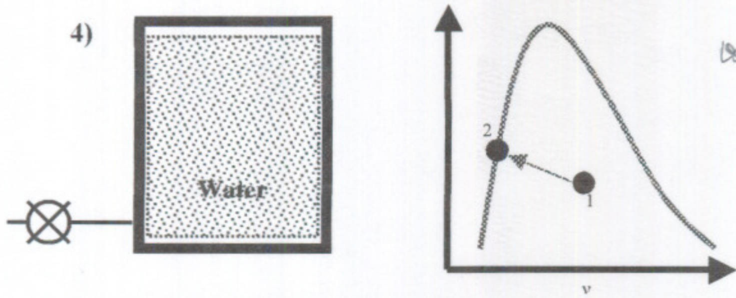
3)





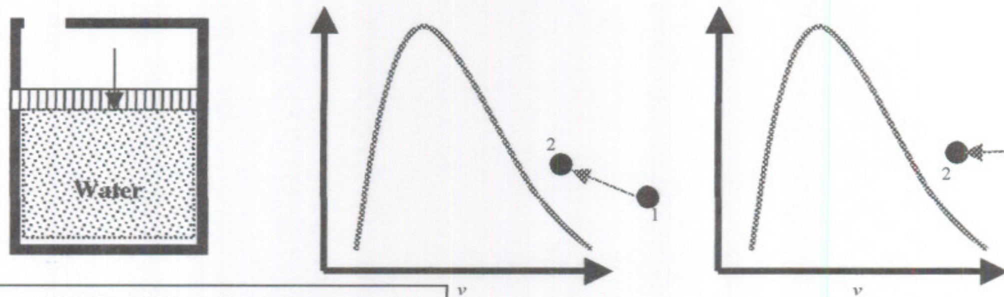
Heat leaves the system.
x_1 undefined, $x_2 = 1$

4)



Mass is added to the system.
Process is adiabatic.
x_1 defined, $x_2 = 0$

5)



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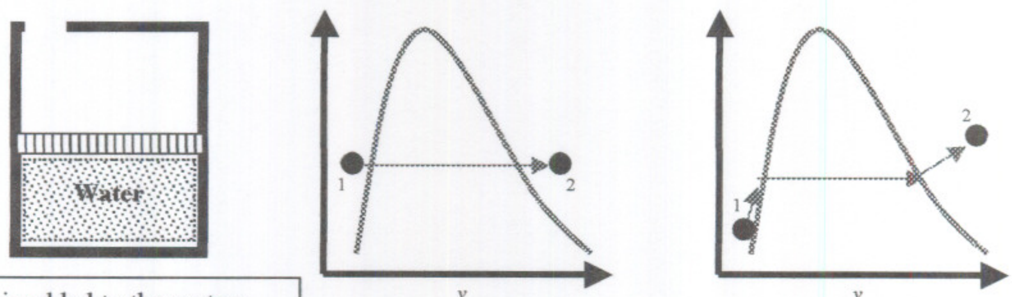

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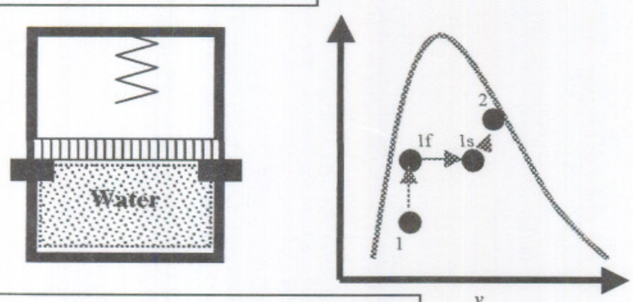
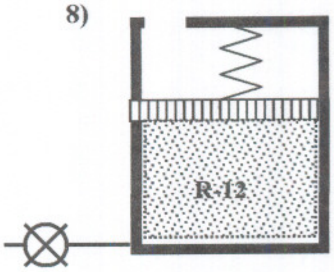
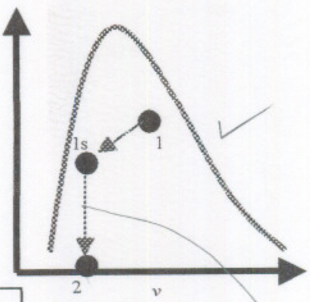


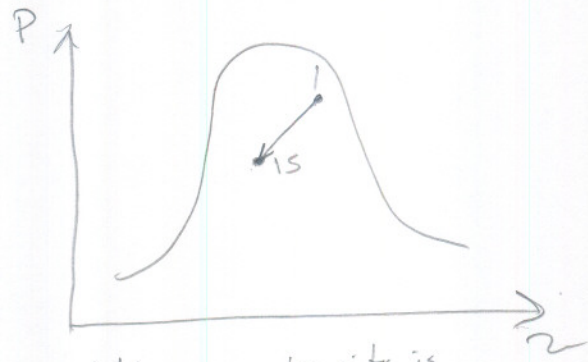
Heat is added to the system.
x is always defined. $P_1 < P_{float}$

8)





~~I think this should be~~

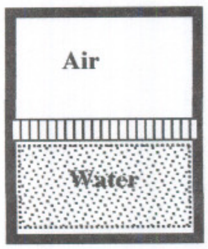


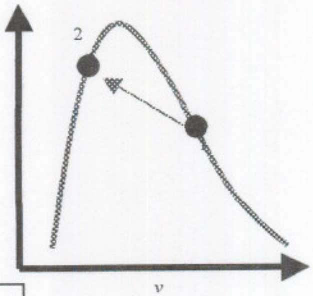
Spring is compressed initially.
All mass leaves the system.
Initial quality is defined.

but this means density is constant, and pressure decreases

OK.

9)





Heat is added to the **air**.
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Water is insulated.
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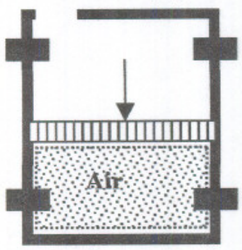
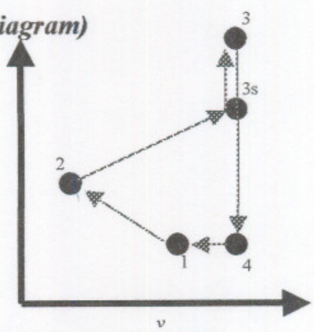
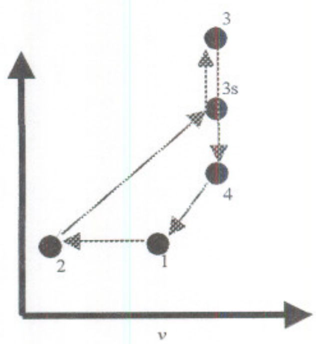
Bonus Problem *(2 points per diagram)*







Multi-Stage Process

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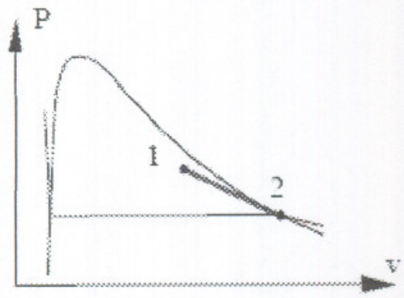
- Pressure is now greater than initial pressure and pressure after compression.
- Piston then cools back to ambient conditions.

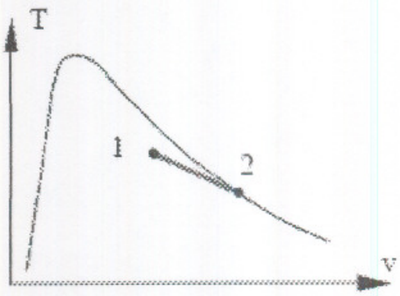
Discussion Questions – Set #2

5.47

1. Problem Statement:

An insulated cylinder fitted with a piston contains R-12 at 25°C with a quality of 90% and a volume of 45 L. The piston is allowed to move, and the R-12 expands until it exists as saturated vapor. During this process the R-12 does 7.0 kJ of work against the piston. Determine the final temperature, assuming the process is adiabatic.





2. Assumptions and Givens:

Take C.V. to be the R-12
Process is adiabatic

State 1: T_1, x_1, V_1

Process: ${}_1W_2$ Work is done

State 2: x_2

Find: T_2

3. Fundamental Laws:

Continuity:
$m_1 = m_2 = m$

Energy Equation (First Law):

$$U_2 - U_1 + \frac{m(\vec{V}_2^2 - \vec{V}_1^2)}{2} + mg(Z_2 - Z_1) = {}_1Q_2 - {}_1W_2$$

$$v = \frac{V}{m}$$
$$v = v_f + xv_{fg}$$
$$u = u_f + xu_{fg}$$

4. **Steps:**

This is an adiabatic process, with no change in kinetic or potential energy. So:

$$U_2 - U_1 = {}_1W_2$$
$$m(u_2 - u_1) = {}_1W_2$$

Using Table B.1.1 and State 1:

$$T_1, x_1 \Rightarrow v_{f1}, v_{g1}, v_{fg1}, u_{f1}, u_{g1}, u_{fg1}$$
$$v_1 = v_{f1} + x_1 v_{fg1}$$
$$m = \frac{V_1}{v_1}$$
$$u_1 = u_{f1} + x_1 u_{fg1}$$

For State 2 we only know 1 independent property: so we apply the energy equation:

$$m(u_2 - u_1) = W_2 \Rightarrow u_2$$
$$u_2 = u_g \text{ because } x_2 = 1$$

Now we have two independent properties so we can use table B.2.1 to find T_2

5. **Numerical Substitution:**

State 1: (T, x) Tabel B.3.1 =>

$v_1 = 0.000763 + 0.9 \times 0.02609 = 0.024244$ m^3/kg

$m = V_1/v_1 = 0.045/0.024244 = 1.856$ kg

$u_1 = 59.21 + 0.9 \times 121.03 = 168.137$ kJ/kg

State 2: (x = 1, ?) We need one property information.

${}_1Q_2 = 0 = m(u_2 - u_1) + {}_1W_2 = 1.856 \times (u_2 - 168.137) + 7.0$

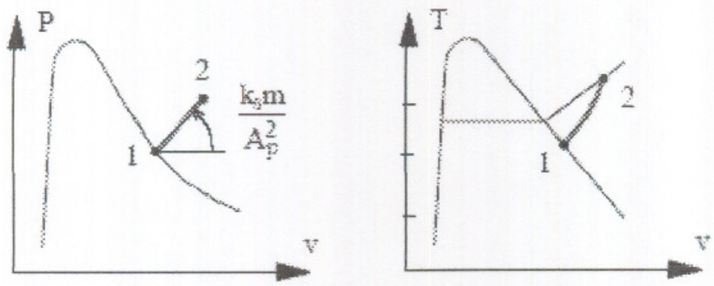
=> $u_2 = 164.365$ kJ/kg $= u_g$ at T_2

Table B.3.1 gives u_g at different temperatures: $T_2 \cong -15°C$

5.57

1. **Problem Statement:**

A cylinder having a piston restrained by a linear spring (of spring constant 15 kN/m) contains 0.5 kg of saturated vapor water at 120°C, as shown in Fig. P5.57. Heat is transferred to the water, causing the piston to rise. If the piston cross-sectional area is 0.05 m^2, and the pressure varies linearly with volume until a final pressure of 500 kPa is reached. Find the final temperature in the cylinder and the heat transfer for the process.



2. **Assumptions and Givens:**

C.V. is water in the cylinder

State 1: T_1, x_1, k_s, A_p

Process: Heat is transferred and the piston moves

State 2: P_2

Find: $T_2, {}_1Q_2$

3. **Fundamental Laws:**

Continuity:

$m_1 = m_2 = m$

Energy Equation (First Law):

$$U_2 - U_1 + \frac{m(\vec{V}_2^2 - \vec{V}_1^2)}{2} + mg(Z_2 - Z_1) = {}_1Q_2 - {}_1W_2$$

4. **Steps:**

We can simplify the energy equation knowing that there is no KE or PE.

$U_2 - U_1 = {}_1Q_2 - {}_1W_2$

$m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Using Table B.1.1 and knowing two independent properties we can find:
$T_1, x_1 \Rightarrow v_1 = v_{g1}, u_1 = u_{g1}$

From previous problems we know that for a spring attached to a piston:
$$P_2 = P_1 + \frac{k_s m}{A_p^2}(v_2 - v_1) \Rightarrow v_2$$
Now we have two independent properties of state 2:
$P_2, v_2 \Rightarrow v_1 = T_2, u_2$

Now that we have the final temperature to find the heat transfer we use the energy equation. In this case since the relationship between P and V is linear we can use the following to calculate the work:
$$_1W_2 = \int PdV = \tfrac{1}{2}(P_1 + P_2)m(v_2 - v_1)$$

Therefore, we now have all the information to find the heat transfer:
$$_1Q_2 = m(u_2 - u_1) + {_1W_2}$$

5. **Numerical Substitution:**

State 1: (T, x) Table B.1.1 => $v_1 = 0.89186\ m^3/kg$, $u_1 = 2529.2\ kJ/kg$

Process: $P_2 = P_1 + \frac{k_s m}{A_p^2}(v_2 - v_1) = 198.5 + \frac{15 \times 0.5}{(0.05)^2}(v_2 - 0.89186)$

State 2: $P_2 = 500$ kPa and on the process curve (see above equation).

=> $v_2 = 0.89186 + (500 - 198.5) \times (0.05^2/7.5) = 0.9924\ m^3/kg$

(P, v) Table B.1.3 => $T_2 = 803°C$; $u_2 = 3668\ kJ/kg$

$$W_{12} = \int PdV = \left(\frac{P_1 + P_2}{2}\right) m(v_2 - v_1)$$
$$= \left(\frac{198.5 + 500}{2}\right) \times 0.5 \times (0.9924 - 0.89186) = 17.56\ kJ$$

$$_1Q_2 = m(u_2 - u_1) + {_1W_2} = 0.5 \times (3668 - 2529.2) + 17.56 = \mathbf{587\ kJ}$$

5.69

1. **Problem Statement:**

The cylinder volume below the constant loaded piston has two compartments A and B filled with water. A has 0.5 kg at 200 kPa, 150°C and B has 400 kPa with a quality of 50% and a volume of 0.1 m^3. The valve is opened and heat is transferred so the water comes to a uniform state with a total volume of 1.006 m^3.

a) Find the total mass of water and the total initial volume.

b) Find the work in the process

c) Find the process heat transfer.

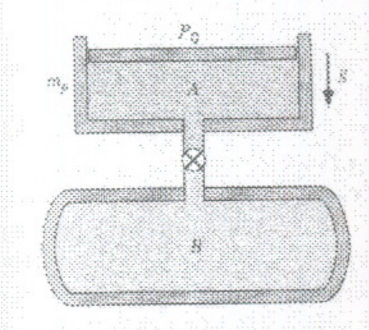


FIGURE P5.69

2. **Assumptions and Givens:**

CV is water in A and B

State 1A: m_{1A}, P_{1A}, T_{1A}

State 1B: P_{1B}, x_{1B}, V_{1B}

Process: Heat is transferred and valve is opened

State 2: V_2

Find: See Problem statement

3. **Fundamental Laws:**

Continuity:

$m_{1A} + m_{1B} = m_2 = m$

Energy Equation (First Law):

$$U_2 - U_1 + \frac{m(\vec{V}_2^{\,2} - \vec{V}_1^{\,2})}{2} + mg(Z_2 - Z_1) = {}_1Q_2 + {}_1W_2$$

$$v = \frac{V}{m}$$
$$v = v_f + xv_{fg}$$
$$u = u_f + xu_{fg}$$

4. **Steps:**

Simplifying the Energy equation gives us:
$$U_2 - U_1 = {}_1Q_2 - {}_1W_2$$
$$m_2u_2 - (m_{1A}u_{1A} + m_{1B}u_{1B}) = {}_1Q_2 - {}_1W_2$$
$$m_2u_2 - m_{1A}u_{1A} - m_{1B}u_{1B} = {}_1Q_2 - {}_1W_2$$

a) If $V_2 > V_B$ then the piston will never hit the stops and P is constant.

Using Table B.1.3 we can find the properties of State 1A:
$$T_{1A}, P_{1A} \Rightarrow v_{1A}, u_{1A}$$
$$V_{1A} = m_{1A}v_{1A}$$
$$\therefore V_1 = V_{1A} + V_{1B}$$
Now we can compare V_1 to V_2

Using Table B.1.2 we can find the properties of State 1B:
$P_{1B}, x_{1B} \Rightarrow v_{1A}, u_{1A}$ using quality relationships
$$m_{1B} = V_{1B} / v_{1B}$$
$$\therefore m_{tot} = m_{1A} + m_{1B} = m_2$$

$$\therefore v_2 = V_2 / m_2$$

Now we can find out all the information about State 2, using table B.1.3
$$P_2, v_2 \Rightarrow T_2, u_2$$

b) Since the final volume is bigger than the initial volume, that means the piston floats so it is constant pressure. There the work is:
$${}_1W_2 = \int PdV = P\Delta V = P_{float}\Delta V = P_2(V_2 - V_1)$$

c) Finally, using the energy equation we solve for heat.
$${}_1Q_2 = {}_1W_2 + m_2u_2 - m_{1A}u_{1A} - m_{1B}u_{1B}$$

5. Numerical Substitution:

State A1: Sup. vap. Table B.1.3 $v = 0.95964 \text{ m}^3/\text{kg}$, $u = 2576.9$ kJ/kg

$$\Rightarrow V = mv = 0.5 \times 0.95964 = 0.47982$$

State B1: Table B.1.2 $v = (1\text{-}x) \times 0.001084 + x \times 0.4625 = 0.2318 \text{ m}^3/\text{kg}$

$$\Rightarrow \quad m = V/v = 0.4314 \text{ kg}$$

$$u = 604.29 + 0.5 \times 1949.3 = 1578.9 \text{ kJ/kg}$$

State 2: 200 kPa, $v_2 = V_2/m = 1.006/0.9314 = 1.0801 \text{ m}^3/\text{kg}$

Table B.1.3 $\Rightarrow$ close to $T_2 = 200°C$ and $u_2 = 2654.4$ kJ/kg

So now

$$V_1 = 0.47982 + 0.1 = \mathbf{0.5798 \ m^3}, \ m_1 = 0.5 + 0.4314 = \mathbf{0.9314 \ kg}$$

Since volume at state 2 is larger than initial volume piston goes up and the pressure then is constant (200 kPa which floats piston).

$${}_1W_2 = \int P\, dV = P_{lift} (V_2 - V_1) = 200\ (1.006 - 0.57982) = \mathbf{85.24 \ kJ}$$

$${}_1Q_2 = m_2u_2 - m_{1A}u_{1A} - m_{1B}u_{1B} + {}_1W_2$$
$$= 0.9314 \times 2654.4 - 0.5 \times 2576.9 - 0.4314 \times 1578.9 + 85.24 = \mathbf{588 \ kJ}$$