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Course: MAE 91

Set: #3

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See prob 4.54

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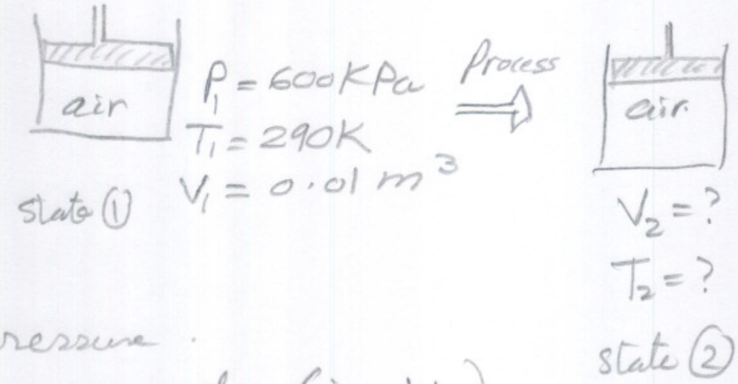
Bonus 25/25

problem 4.34 90/10

given a piston/cylinder



the process is a constant pressure.
system gives 54KJ of work out. (i.e $_1W_2$)
Find T_2.

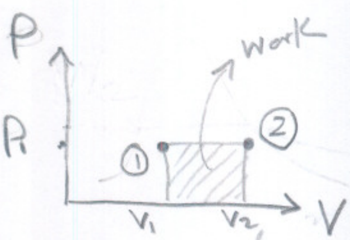
Assumptions

- Frictionless piston. (this assumption is probably not needed here)
- ideal gas

Laws

for ideal gas use $PV = mRT$

P-V diagram



$$_1W_2 = \int_1^2 P\,dV$$

steps

we are told that system gives some work out.
hence $_1W_2 = \int_1^2 P\,dV$

but P is constant $\Longrightarrow$ $_1W_2 = P(V_2 - V_1)$

hence solve for V_2 $\Longrightarrow$ $\boxed{V_2 = \frac{_1W_2}{P} + V_1}$ ——— ①

to find T_2, apply equation $PV = mRT$ at state ① and state ②.

$$\left.\begin{aligned} P_1V_1 &= m_1RT_1 \\ P_2V_2 &= m_2RT_2 \end{aligned}\right\}$$ but $m_1 = m_2$ since mass do not change.

so $\frac{\cancel{P_1}V_1}{T_1} = \frac{\cancel{P_2}V_2}{T_2}$ $\Longrightarrow$ solve for $\boxed{T_2 = \frac{\cancel{P_2}V_2}{\cancel{P_1}V_1}T_1}$ ——— ②

$\longrightarrow$

Numerical

to find V_2, from equation ①

$$V_2 = \frac{{}_1W_2}{P_1} + V_1$$

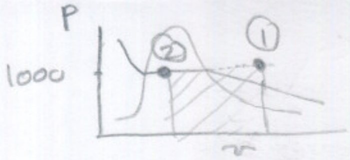
$$= \frac{54 \times 10^3}{600 \times 10^3} + 0.01 = \boxed{0.1\ m^3}$$

To find T_2, from equation ②

$$T_2 = \frac{P_2 V_2}{P_1 V_1} T_1 = \frac{0.1}{0.01} 290 = \boxed{2900\ K}$$

$$= 2900 + 273 = \boxed{3173\ ^\circ C}$$

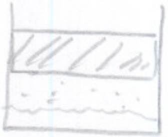
Problem 4.36



10/10

$m_1 = 5\,Kg$
$P_1 = 1000\,KPa$
$T_1 = 140°C$

Process
$\xrightarrow{\hspace{2cm}}$
constant pressure
cooling



$x_2 = .25$

State ①
superheated
phase

State ②
mixed liquid-vapor
saturated phase.

Find work done on process to cool it at constant pressure.

Assumptions

mass same in state ① and ② . i.e control mass.

Laws

$$v = \frac{V}{m}$$

$$_1W_2 = \int_1^2 P\,dV$$

steps

$$_1W_2 = \int_1^2 P\,dV = P_1(V_2 - V_1) \quad \text{(since constant P).}$$

but $\boxed{V_1 = v_1 m_1}$ —— ①

m_1 is given. find v_1 from table B.5.2. (superheated R134a).

to find V_2, since constant pressure, then $P_2 = P_1$

from table B.5.1. (saturated R134a), find v_{f_2}, v_{g_2}.

then $v_2 = v_{f_2} + x_2(v_{g_2} - v_{f_2})$.

but $m_2 = m_1$.

so $V_2 = v_2 m_2 = \boxed{m_2\left(v_{f_2} + x_2(v_{g_2} - v_{f_2})\right)}$ —— ②

from ① and ②

$$_1W_2 = P_1\left[\,m_2\left(v_{f_2} + x_2(v_{g_2} - v_{f_2})\right) - v_1 m_1\right] \longrightarrow$$

Numerical

$${}_1W_2 = P_1\left[\,m_2\left(v_{f_2}+x_2(v_{g_2}-v_{f_2})\right)-v_1 m_1\right]$$

$${}_1W_2 = 1000\times10^3\left[5\left(v_{f_2}+0.25(v_{g_2}-v_{f_2})\right)-v_1\times5\right].$$

from B.5.2, at $P_1 = 1000\ \text{kPa}$, $T_1 = 140°\text{C} \Longrightarrow v_1 = \boxed{0.03150\ \text{m}^3/\text{kg}}$

from B.5.1, use interpalation:

$P = 887.6$ $\quad v_f = 0.000857$ $\quad v_g = 0.0231$
$P = 1017$ $\quad v_f = 0.000873$ $\quad v_g = 0.02002$
$P = 1000$ $\quad v_f = ?$ $\quad v_g = ?$

so
$$\frac{1017-887.6}{1017-1000} = \frac{0.000873-0.000857}{0.000873-v_f}$$

$$\frac{129.4}{17} = \frac{1.6\times10^{-5}}{0.000873-v_f} \Rightarrow (17)(1.6\times10^{-5}) = 129.4(0.000873-v_f)$$

$$2.1\times10^{-6} = 0.000873-v_f \Rightarrow \boxed{v_f = 0.00087089}\ \text{m}^3/\text{kg}$$

to find v_g:
$$\frac{1017-887.6}{1017-1000} = \frac{0.02002-0.0231}{0.02002-v_g}$$

$$7.611764 = \frac{-3.08\times10^{-3}}{0.02002-v_g} \Rightarrow 0.1523875-7.611764\,v_g = -3.08\times10^{-3}$$

$$\boxed{v_g = 0.020424}\ \text{m}^3/\text{kg}.$$

sub. in above equation for ${}_1W_2$ we get

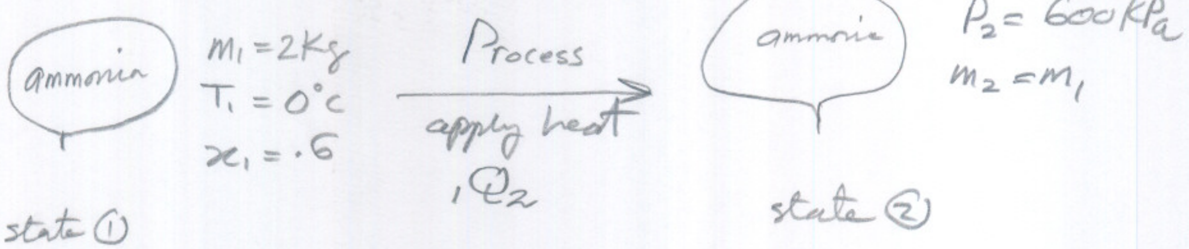
$${}_1W_2 = 1000\times10^3\left[5\left(0.00087089+.25(0.020424-0.00087089)\right)-0.03150\times5\right]$$

$$\boxed{{}_1W_2 = -128704\ \text{J}}$$

problem 4.54

10/10

statment



Find work done in the process. ($_1W_2$)

given Pressure $\propto D^2 \rightarrow$ diameter of balloon. i.e $P = KD^2$ for some constant K.

assumptions

balloon shape is a sphere.

Laws

$v = \frac{V}{m}$, $W = \int_1^2 P\,dV$

Volume of sphere $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 = \frac{4}{3}\pi\frac{D^3}{6} = \frac{2}{9}\pi D^3$

so $D = \left(\frac{9}{2}\frac{V}{\pi}\right)^{1/3}$

steps

To find work done, need to find Volume in state ① and in state ② then apply $\int_1^2 P\,dV$.

in state ①, ammonia is in 2 phase saturated liquid-vapor.

from table B.2.1, look up v_{f_1}, v_{g_1} for T_1.

$v_1 = v_{f_1} + x(v_{g_1} - v_{f_1})$

so $V_1 = v_1 m = m\left[v_{f_1} + x(v_{g_1} - v_{f_1})\right]$ ——— ①

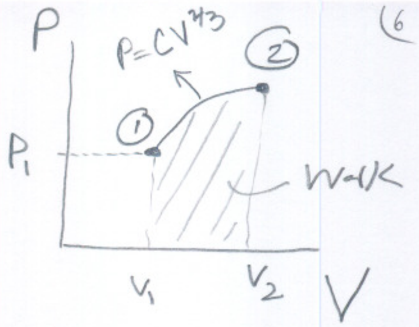
find P_1 also from same table as above.

$P_1 = KD_1^2$. but $V_1 = \frac{2}{9}\pi D_1^3 \Rightarrow D_1^3 = \frac{9}{2}\frac{V_1}{\pi} \Rightarrow D_1 = \left(\frac{9}{2}\frac{V_1}{\pi}\right)^{1/3}$

so $K = \frac{P_1}{D_1^2} = \boxed{\frac{P_1}{\left(\frac{9}{2}\frac{V_1}{\pi}\right)^{2/3}}}$ ——— ②.

now apply $P_2 = KD_2^2$, solve for $D_2 = \sqrt{\frac{P_2}{K}} = \sqrt{\frac{P_2\left(\frac{9}{2}\frac{V_1}{\pi}\right)^{2/3}}{P_1}}$ →

so $D_2 = \sqrt{\frac{P_2}{P_1}} \left(\frac{9}{2}\frac{V_1}{\pi}\right)^{1/3}$



so $V_2 = \frac{2}{9}\pi D_2^3 = \frac{2}{9}\pi \left(\frac{P_2}{P_1}\right)^{3/2} \frac{9}{2}\frac{V_1}{\pi}$

$$\boxed{V_2 = \left(\frac{P_2}{P_1}\right)^{3/2} V_1} \quad ③$$

now that we know V_1 and V_2, we can find work

$$_1W_2 = \int_1^2 P\,dV$$

P is a function of V so can not be moved out.

$$P = K D^2 = K\left(\frac{9}{2}\frac{V}{\pi}\right)^{2/3}$$

so $_1W_2 = \int_1^2 K\left(\frac{9}{2}\frac{V}{\pi}\right)^{2/3} dV = K\left(\frac{9}{2\pi}\right)^{2/3} \int_1^2 V^{2/3} dV$

$$= K\left(\frac{9}{2\pi}\right)^{2/3} \left[\frac{3}{5}V^{5/3}\right]_{V_1}^{V_2} = \boxed{\frac{3K}{5}\left(\frac{9}{2\pi}\right)^{2/3}\left[V_2^{5/3} - V_1^{5/3}\right]} \quad ④$$

$$= \frac{P_2V_2 - P_1V_1}{1-n}$$

where K is a constant $\boxed{K = \frac{P_1}{\left(\frac{9}{2}\frac{V_1}{\pi}\right)^{2/3}}}$

Numerical

$P_1 = 429.6$ kPa, $v_{f_1} = 0.001566$ m³/kg, $v_{g_1} = 0.28920$ m³/kg.

from eq ①, $V_1 = m_1\left[v_{f_1} + x_1(v_{g_1} - v_{f_1})\right] = 2\left[0.001566 + .6(0.28920 - 0.001566)\right]$

$= \boxed{0.348294 \text{ m}^3}$

from eq ② $K = \frac{P_1}{\left(\frac{9}{2}\frac{V_1}{\pi}\right)^{2/3}} = \frac{429.6 \times 10^3}{\left(\frac{9}{2}\frac{0.348294}{\pi}\right)^{2/3}} = \boxed{682954.62}$

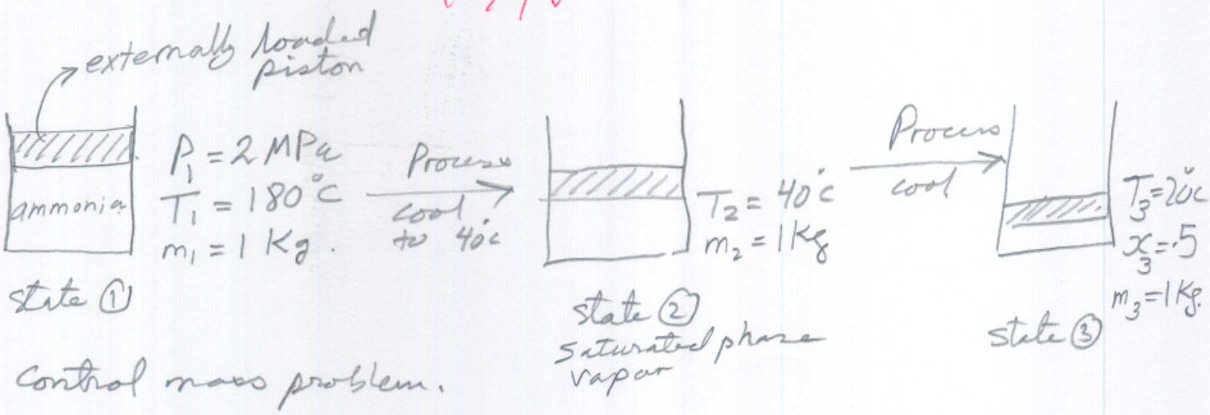
from ③ $V_2 = \left(\frac{P_2}{P_1}\right)^{3/2} V_1 = \left(\frac{600 \times 10^3}{429.6 \times 10^3}\right)^{3/2} 0.348294 = \boxed{0.574879 \text{ m}^3}$

from eq ④ $_1W_2 = \frac{3}{5}\, 682954.62 \left(\frac{9}{2\pi}\right)^{2/3}\left[0.574879^{5/3} - 0.348294^{5/3}\right] = \boxed{117180.17 \text{ J}}$

problem 4.60

10/10

statment



this is a control mass problem.
find total work done.

Assumptions

control mass
pure substance
ideal process
piecewise linear variation of P vs. V.

Laws

$$v = \frac{V}{m}$$

$$_1W_3 = {}_1W_2 + {}_2W_3$$

$$_iW_j = \int_i^j P\,dV$$

Steps

to find total work, need to find pressure and Volume at each state. Then use $\int_1^2 P\,dV = {}_1W_2$

V_1 is found by looking up table B.2.2 (superheated ammonia table) using (P, T) at state 1. I know phase is Superheated since looking up B.2.1 shows that at $P = P_1$, $T_{sat} < T_1$, hence must be superheated.

so $\boxed{V_1 = v_1 m_1}$ ——— ①

now since in state ② it just entered saturated vapor, so $x = 1$ and $v_2 = v_g$. so use table B.2.1 to look up v_g for $T = T_2$. and since $m_2 = m_1$ then

$\boxed{V_2 = v_{g_2} m_1}$ ——— ② also look up P_2 from same table. ⟶

now to find V_3, look up table B.2.1 for $T=T_3$ and find v_{f_3}, v_{g_3}:

hence $V_3 = m_1 \left[v_{f_3} + x_3 (v_{g_3} - v_{f_3}) \right]$ (since $m_3 = m_1$)

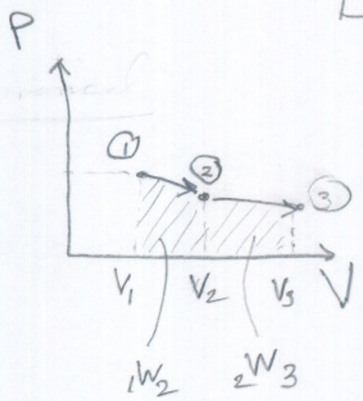
Also lookup P_3.

So now we can find work.

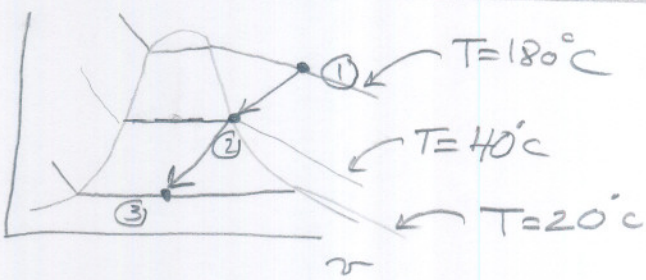
$$ {}_1W_2 = \int_1^2 P\,dV = \tfrac{1}{2}(P_1+P_2)(V_2-V_1) = \tfrac{1}{2}(P_1+P_2)(v_{g_2} m - v_1 m) $$

$$ {}_2W_3 = \int_2^3 P\,dV = \tfrac{1}{2}(P_2+P_3)(V_3-V_2) = \tfrac{1}{2}(P_2+P_3)\left(m(v_{f_3}+x_3 v_{fg_3}) - m v_{g_2}\right) $$

so total work $= \boxed{\tfrac{1}{2}(P_1+P_2)(v_{g_2} m - v_1 m) + \tfrac{1}{2}(P_2+P_3)\left(m(v_{f_3}+x_3 v_{fg_3}) - m v_{g_2}\right)}$



P–V diagram for the process



P–v diagram for the process

Numerical

look up values for v_1, v_{g_2}, v_{f_3}, v_{fg_3}, P_2, P_3

$v_1 = 0.10571$ Kg/m³, $v_{g_2} = 0.08313$ Kg/m³, $v_{f_3} = 0.001638$, $v_{fg_3} = 0.14758$ m³/Kg.

$P_2 = 1554.9$ KPa, $P_3 = 857.5$ KPa

hence from above equation for W

$$ {}_1W_3 = \tfrac{1}{2}(2\times10^6 + 1554.9\times10^3)(0.08313 - 0.10571)\times 1 + \tfrac{1}{2}(1554.9\times10^3 + 857.5\times10^3)((0.001638 + .5\times 0.14758) - 0.08313) $$

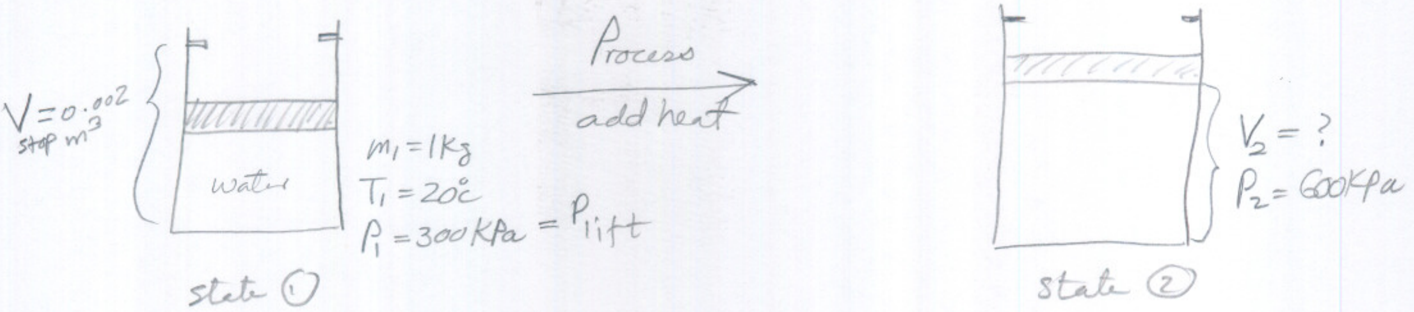
$$ = -40134.8 - 9290.15 = \boxed{-49424.9 \text{ J}} $$

Since work is negative, this means work is done by the system not to it.

Problem 4.67

10/10

Statment



Find final volume V_2 and Work done
in state ①, piston floats. i.e $P_1 = P_{lift}$

Assumptions

control mass. so $m_2 = m_1$
ideal process

Laws

$$ {}_1W_2 = \int_1^2 P\,dV $$

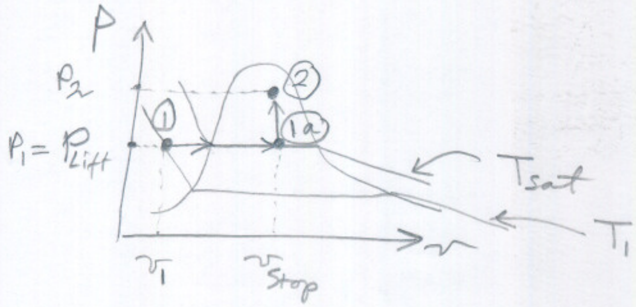
$v = \frac{V}{m}$, tables B.1.1, B.1.4.

steps

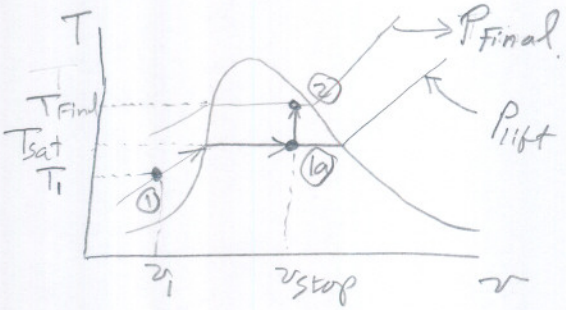
first find the phase of state ①.
from table B.1.1 look up P_{sat} for T_1. we find that
$P_1 > P_{sat}$, hence phase is compressed liquid.
so use B.1.4 to find v_1 for (T_1, P_1).

As heat is being added, V_1 is not changing while water is still in compressed liquid state.
when Temp. reaches T_{sat} corresponding to P_1, then 2phase saturated liquid-vapor phase starts, and now pressure remains constant at P_{lift} while volume increases.
since $P_{final} > (P_{lift} = P_1)$, then this means final volume is V_{stop}.
hence $ {}_1W_2 = \int_1^2 P\,dV = \boxed{P_{lift}\ m(v_{stop} - v_1)} \longrightarrow$

hence the P–v diagram will look like this:



state ①: initial state
state (1a): when piston hits stop
state ②: Final state when $P = P_{final}$



Numerical

given $P_{Lift} = 300 \text{ KPa}$

from table B.1.4., no entry for P = 300 KPa, use lowest entry 500KPa, look under T = 20°c $\Longrightarrow \boxed{v_1 = 0.001002}\ m^3/Kg.$

$$v_{Stop} = \frac{V_{total}}{m} = \frac{0.002\ m^3}{1\ Kg} = \boxed{0.002}\ m^3/kg$$

hence $_1W_2 = (300)(1\ Kg)(0.002 - 0.001002)$

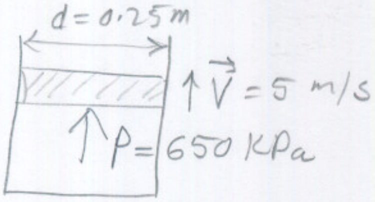
$$= \boxed{0.2994\ J}$$

Problem 4.91

10/10

statment

pressure of 650 KPa pushes piston, diameter = 0.25 m, with $\vec{V} = 5$ m/s. Find volume displacment rate, force, and transmitted power.



Assumptions

Laws

$$P = \frac{F}{A}$$

Volume of a cylindrical section  $= Ah$

hence $\frac{dV}{dt} = \vec{V} A$

Power = rate of doing work $= P \frac{dV}{dt}$ (since P is constant).

$A = \pi r^2$, where $r = \frac{d}{2}$

steps

Find A

find $\frac{dV}{dt}$ using Law $\frac{dv}{dt} = \vec{V} A$.

find power $= P \frac{dV}{dt}$

find Force = PA.

Numerical

$$A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \pi \left(\frac{0.25}{2}\right)^2 = 0.049087 \text{ m}^2$$

$$\frac{dV}{dt} = \vec{V} A = (5)(0.049087) = \boxed{0.245436} \text{ m}^3/\text{s}$$

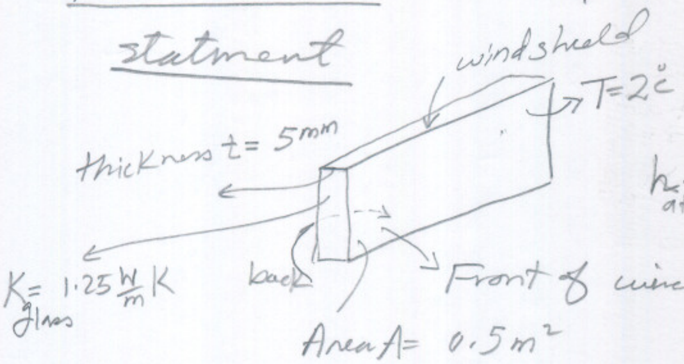
$$\text{Power} = P \frac{dv}{dt} = (650 \times 10^3)(0.245436) = \boxed{159534} \text{ Watt}$$

$$\text{Force} = PA = (650 \times 10^3)\, 0.049087 = \boxed{31906.55} \text{ N}$$

Problem 4.98

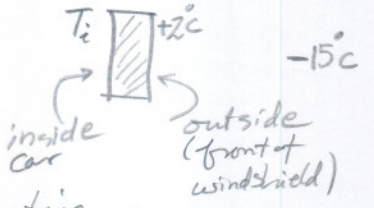
P/10

statment



$T_{atm} = -15°c$

$h_{atm} = 250\ W/m^2\ K$ (convection coefficient)



Find rate of energy loss from front of windshield

Find the inside the car windshield surface temp.

Assumptions

heat loss in front is due to convection.

heat loss in window is due to conduction.

Laws

heat loss from front of windshield using Newton law of cooling $\dot{Q} = A\,h\,\Delta T$

heat loss in glass is due to conduction (Fourier Law)

$$\dot{Q} = -KA\,\frac{dT}{dx}$$

steps

apply Newton Law of cooling.

$\Delta T = T_{front\ of\ glass} - T_{atm}$.

h is given. so $\dot{Q}$ is found from $\dot{Q} = Ah\,\Delta T$ —— ①.

Now to find inside windshield temp, apply conduction Law.

let inside $T = T_{inside}$.

hence $\dot{Q} = KA\left(\dfrac{T_{inside} - T_{outside}}{\text{thickness}}\right)$ —— ②

but rate of heat loss in the glass must be the same as rate of heat loss due to convection. ⟶

hence using ① and ②, solve for T_{inside}:

② becomes after substituting ① into it:

$$A h \Delta T = -KA\left(\frac{T_{inside} - T_{outside}}{thickness}\right)$$

$$A h \left(T_{outside} - T_{atm}\right) = KA\left(\frac{T_{inside} - T_{outside}}{thickness}\right)$$

let $T_{outside} = T_o$

$T_{atm} = T_a$

$thickness = t$

hence $\cancel{A} h\,(T_o - T_a) = K\cancel{A}\left(\frac{T_i - T_o}{t}\right)$

$$\frac{th}{K}(T_o - T_a) = T_i - T_o$$

$$\boxed{T_i = T_o + \frac{th}{K}(T_o - T_a)} \text{ — ③}$$

Numerical

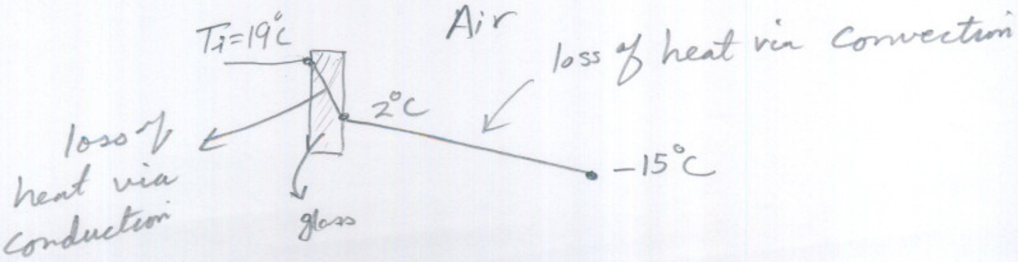
from ①, $\dot{Q} = Ah\,(T_o - T_a) = (0.5)(250)(2-(-15))$

$= \boxed{2125 \text{ Watt}}$

from ③

$$T_i = 2 + \frac{(5\times10^{-3})(250)}{1.25}\left(2-(-15)\right) = 2 + 17$$

$$\boxed{T_i = 19^\circ c}$$

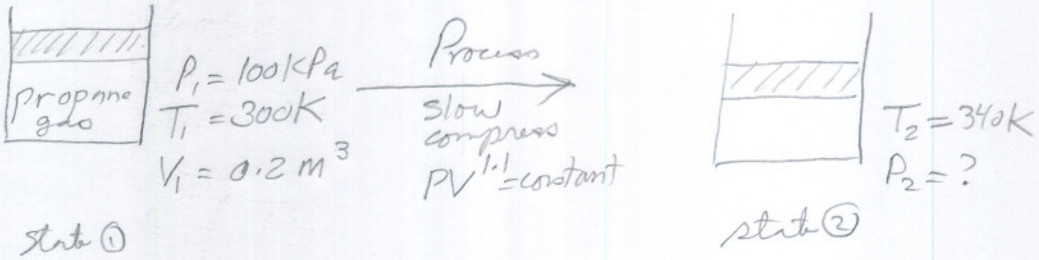


10/10

Problem 4.108

Statment

given



find P_2 and work done during process.
and justify use of ideal gas Law.

Assumptions

control mass. so $m_2 = m_1$

Laws

$PV = mRT$ ideal gas

$\int_1^2 PdV = \frac{P_2V_2 - P_1V_1}{1-n}$ when PV^n=constant $\longrightarrow$

~~steps~~

~~we are given that $PV^{1.1}$ = constant.~~

~~so $P_1V_1^{1.1} = P_2V_2^{1.1}$~~

~~so $V_2 = \left(\frac{P_1}{P_2}V_1^{1.1}\right)^{\frac{1}{1.1}}$ —— ①~~

~~V_1 and P_1 are given. so need to find V_2.~~

~~from ideal gas Law $P_2V_2 = mRT_2$ —— ②~~

~~so from ② $P_2 = mR\frac{T_2}{V_2}$~~

~~sub ① into ② $\Rightarrow P_2 = mR\frac{T_2}{\left(\frac{P_1}{P_2}V_1^{1.1}\right)^{\frac{1}{1.1}}}$~~

steps

since $PV^{1.1} = \text{constant}$. let $n = 1.1$

so $PV^n = \text{constant}$.

so $\boxed{P_1 V_1^n = P_2 V_2^n}$

so $P_2 = P_1 \left(\frac{V_1}{V_2}\right)^n$ —— ①

but $PV = mRT$ for an ideal gas.

so $P_2 V_2 = mRT_2 \Rightarrow V_2 = \frac{mRT_2}{P_2}$ —— ②

sub ② into ① $\Rightarrow P_2 = P_1 \frac{V_1^n}{\left(mR\frac{T_2}{P_2}\right)^n} = \frac{P_1 V_1^n P_2^n}{m^n R^n T_2^n}$

so $P_2^{n-1} = \frac{(mRT_2)^n}{P_1 V_1^n} = \frac{1}{P_1}\left(\frac{mRT_2}{V_1}\right)^n$

so $\boxed{P_2 = \left[\frac{1}{P_1}\left(\frac{mRT_2}{V_1}\right)^n\right]^{\frac{1}{n-1}}}$ where $n = 1.1$

to find m. use ideal law at state ①.

$P_1 V_1 = mRT_1 \Longrightarrow \boxed{m = \frac{P_1 V_1}{RT_1}}$.

so $P_2 = \left[\frac{1}{\cancel{P_1}}\left(\frac{\cancel{P_1}\cancel{V_1}\cancel{R}T_2}{\cancel{R}T_1\cancel{V_1}}\right)^n\right]^{\frac{1}{n-1}} = P_1^{\frac{n-1}{n-1}}\left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}$

so $\boxed{P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}}$ —— ③

so we find P_2 since P_1, T_2, T_1 are given and n is given as 1.1. ⟶

now to find ${}_1W_2$, need to find V_2

since $P_1 V_1^n = P_2 V_2^n$

then $$V_2 = \left(\frac{P_1}{P_2} V_1^n\right)^{\frac{1}{n}} = \boxed{V_1 \left(\frac{P_1}{P_2}\right)^{\frac{1}{n}}} \text{ ——— } ④$$

so we find V_2 since we found P_2 in ③ and are given V_1 and P_1.

so to find work, we

$${}_1W_2 = \int_1^2 P\,dV = \boxed{\frac{P_2 V_2 - P_1 V_1}{1-n}} \text{ ——— } ⑥$$

now need to justify ideal gas law usage in this problem.

in ideal gas, $\frac{PV}{mRT} = 1$ or $\frac{Pv}{RT} = 1$

so calculate $\frac{P_1 v_1}{RT_1}$ and $\frac{P_2 v_2}{RT_2}$ and see how far from value 1 we get. if difference is small, then we are justified to use ideal gas law.

Numerical

⟶

Numerical

using equation ③ $P_2 = P_1 \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}$

where $n=1.1$, $P_1 = 100\text{ kPa}$, $T_1 = 300\text{ K}$, $T_2 = 340\text{ K}$.

then $P_2 = 100\times10^3 \left(\frac{340}{300}\right)^{\frac{1.1}{.1}} = 396218\text{ Pa}$

$= \boxed{396.218\text{ kPa}}$

from equation ④

$$V_2 = V_1 \left(\frac{P_1}{P_2}\right)^{\frac{1}{n}}$$

so $V_2 = 0.2 \left(\frac{100}{396.218}\right)^{\frac{1}{1.1}} = \boxed{0.057207\text{ m}^3}$

$${}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{(396.2\times10^3)(0.057207) - (100\times10^3)(0.2)}{1-1.1}$$

$= \boxed{-26654.13\text{ J}}$ or $\boxed{-26.65\text{ kJ}}$

now evaluate $Z = \frac{P_1 v_1}{RT_1}$. from Table A.5, for Propane, $R = 0.1886\text{ kJ/kg·K}$

$\rho = 1.808\text{ kg/m}^3$ so $v_1 = 1/\rho$ so $Z = \frac{(100\times10^3)(1/1.808)}{(0.1886)(\times10^3)(300)} = \boxed{0.977}$

evaluate at state ②.

$Z = \frac{P_2 v_2}{RT_2} = \frac{(396.218\times10^3)\left(\frac{1}{1.808}\right)}{(0.1886)\times10^3\times340} = \cancel{3.4}$ .95

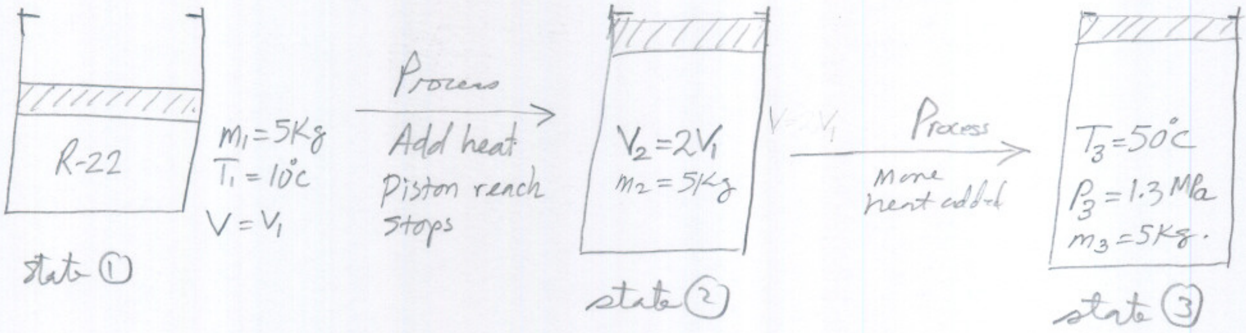
← recheck values they should be okay

at state ① we are close to 1, so there more justified to use ideal gas model. in state ② model of ideal gas is not as well justified.

Problem 5.64

10/10

statment



Find
a) quality in state ①
b) Total heat transfer from state ① to state ③

Assumptions

- ideal process
- pure substance
- frictionless piston .
- control mass i.e $m_1 = m_2 = m_3$

Laws

$v = \frac{V}{m}$

first Law of thermodynamics $\Delta U + \Delta PE + \Delta KE = {}_iQ_j - {}_iW_j$

${}_1W_2 = \int_1^2 P\,dV$

steps

a) to find quality in state ① we need to find V_1. but in state ① only know one property T_1. But since in state ③ we are given 2 independent properties (P,T) we can find V_3 there. and since $V_3 = 2V_1$, $\boxed{\text{we find } V_1.}$ this gives v_1 , and now can use table B.4.1 to find v_f and v_g and solve for x using $\overset{\checkmark}{v_1} = \overset{\checkmark}{v_{f_1}} + x_1(\overset{\checkmark}{v_{g_1}} - \overset{\checkmark}{v_{f_1}})$

$$\boxed{x_1 = \frac{v_1 - v_{f_1}}{v_{fg_1}}}$$

→

b) to find total heat transfer, use the first Law of thermodynamics

i.e $\quad {}_1Q_3 = {}_1Q_2 + {}_2Q_1$

where $\quad U_3 - U_1 = {}_1Q_3 - \boxed{{}_1W_3} = {}_1W_2$ since $\Delta V = 0$ from state ② to state ③.

(since $\Delta PE = 0$ and $\Delta KE = 0$).

so $\quad U_3 - U_1 = {}_1Q_3 - {}_1W_2$

To find ${}_1W_2$, we find P_1 from Tables B.4.1 since we know T_1 in state ①. and since piston is free to move from ①→②, then $P_2 = P_1$, i.e constant P.

so $\boxed{{}_1W_2 = P_1(V_2 - V_1) = P_1(2V_1 - V_1) = P_1V_1}$

and we know V_1 which we found in part ⓐ.

now need to find U_3 and U_1.

from table B.4.1 we find u_{f_1} and u_{g_1}, and since we found x_1 in part ⓐ, then we find

$\boxed{u_1 = u_{f_1} + x_1(u_{g_1} - u_{f_1})}$ and $U_1 = m u_1$

now need to find U_3.

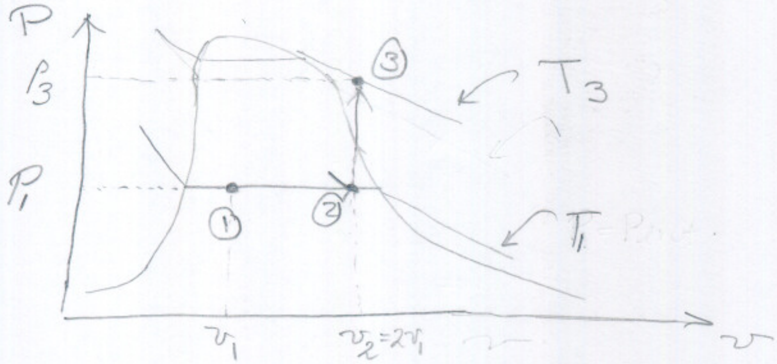
in state ③ we are given 2 properties (T, P) so use table B.4.2 to find u_3, and since $m_3 = m_1$ (control mass) then $U_3 = m u_3$.

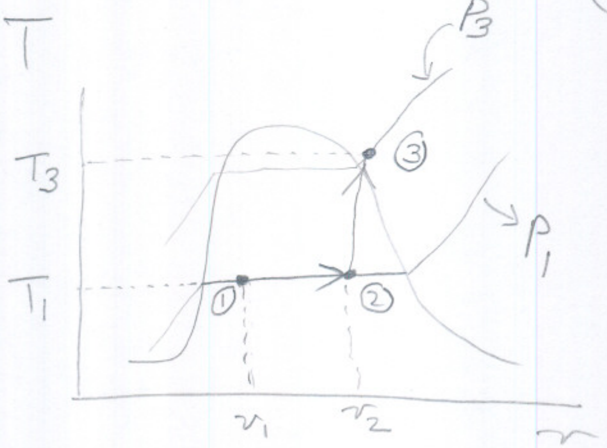
hence $\quad {}_1Q_3 = (U_3 - U_1) + {}_1W_2$

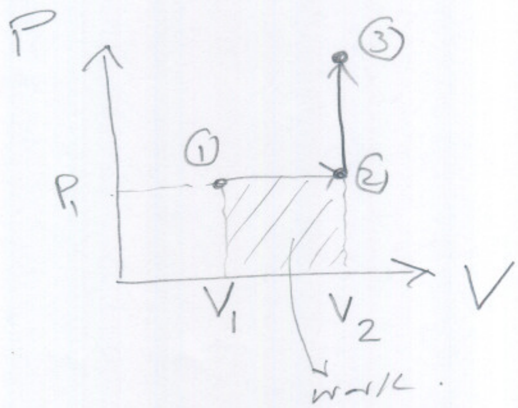
$$\boxed{{}_1Q_3 = mu_3 - m(u_{f_1} + x_1(u_{g_1} - u_{f_1})) + P_1V_1}$$

→

state change diagrams:







Numerical

a) using state ③ properties $T_3 = 50^\circ c$, $P_3 = 1.3\ MPa$

from Table B.4.1, we see at $T_3 = 50^\circ c$, $P_{sat} = 1.942\ MPa$.

so $P_{sat} > P_3$, so in superheated phase. so use table B.4.2. need to do interpolation: (all for $T = 50^\circ c$)

$P = 1.2\ MPa$ $v = 0.02205\ m^3/kg$ $u = 249.55 \times 10^3\ J/kg$

$P = 1.4\ MPa$ $v = 0.01825\ m^3/kg$ $u = 247.22 \times 10^3\ J/kg$.

$$\text{for } \frac{1.4\times10^6 - 1.2\times10^6}{0.02205-0.01825} = \frac{1.4\times10^6 - 1.3\times10^6}{v_3 - 0.01825} \Rightarrow v_3 = \boxed{0.02015\ m^3/kg}$$

$$\text{so from } v = \frac{V}{m} \Rightarrow V_3 = v_3 m = (0.02015)(5) = 0.10075\ m^3.$$

$$\text{so } V_1 = \frac{V_3}{2} = \boxed{0.050375\ m^3} \quad \text{so } v_1 = \frac{V_1}{m} = \frac{0.050375}{5} = \boxed{0.010075\ m^3/kg}$$

now from table B.4.1, find v_{f_1}, v_{fg_1} for $T_1 \Rightarrow$

$v_{f_1} = 0.0008\ m^3/kg$, $v_{fg_1} = 0.03391\ m^3/kg$.

$$\text{so } x_1 = \frac{v_1 - v_{f_1}}{v_{fg_1}} = \frac{0.010075 - 0.0008}{0.03391} = \boxed{0.273518}$$

$\longrightarrow$

b) need to solve for ${}_1Q_3$ using

$${}_1Q_3 = mu_3 - m\left(u_{f_1} + x_1(u_{g_1} - u_{f_1})\right) + P_1V_1$$

find u_3 using data looked up in part ⓐ by interpolation:

$$\frac{1.4\times10^6 - 1.2\times10^6}{(249.55 - 247.22)10^3} = \frac{(1.4-1.3)10^6}{(u_3 - 247.22)\,10^3}$$

so $\boxed{u_3 = 248.385 \text{ J/Kg}}$

P_1 found from table B.4.1 as 680.7 KPa.

also, $u_{f_1} = 55.92\times10^3$ J/Kg, $u_{fg_1} = 173.87\times10^3$ J/Kg

$${}_1Q_3 = (5)(248385) - 5\left(55.92\times10^3 + 0.273518\,(173.87\times10^3)\right) + 680.7\times10^3\,(0.050375)$$

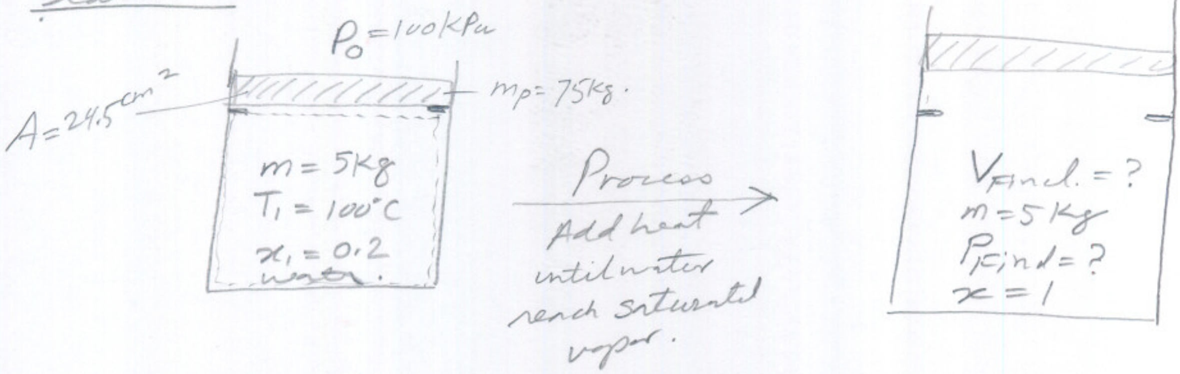
$${}_1Q_3 = 758832.3 \text{ J}$$

$$\boxed{\approx 758.8 \text{ KJ}}$$

Problem 5.73

10/10

statment



Find initial Volume V_1, Final pressure, work, and heat transfer, show P-v diagram.

Assumptions

ideal process, pure substance, frictionless piston.
assume $g = 9.81\ m/s^2$

Laws

$v = \frac{V}{m}$; $(U_2 - U_1) + \Delta PE + \Delta KE = {}_1Q_2 - {}_1W_2$

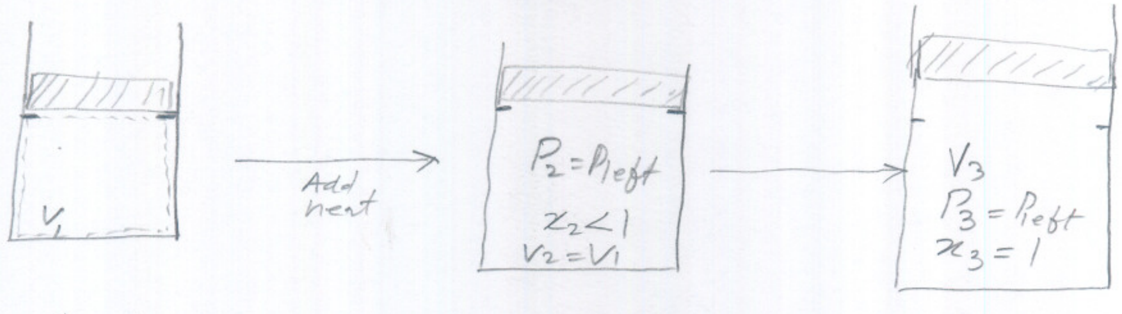
$v = v_f + x\, v_{fg}$

$P = \frac{F}{A}$, ${}_1W_2 = \int_1^2 P\,dV = P(V_2 - V_1)$ for constant P.

Steps

overview: As heat is added, since we start in water-vapor mixed phase, then pressure will increase but volume will remain fixed, until pressure is large enough to reach P_{lift}. at this time, as we add more heat, Pressure will remain constant at P_{lift} but volume will increase as piston moves up. so we have a 3 states process.

⟶



state ①
mixed water vapor phase

state ②
mixed water vapor phase

state ③
just enter
The superheated vapor
phase.

to find initial Volume, since x is defined, then use table B.1.1, Look up v_{f_1}, v_{fg_1} and find v_1 from $v_1 = v_{f_1} + x_1 v_{fg_1}$

so $$\boxed{V_1 = v_1 m = m(v_{f_1} + x_1 v_{fg_1})} \text{ --- } ①$$

since m is given as well.

To find final pressure, this is the same as P_{lift}. using piston force balance, we find P_{left}.

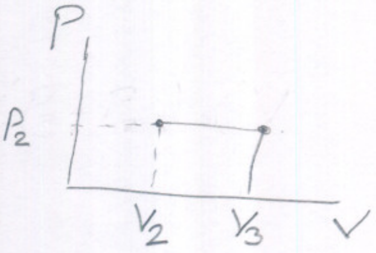
$$P_{left} A = (m_p g) + P_0 A$$

so $$\boxed{P_{left} = \frac{m_p g}{A} + P_0} \text{ ② }$$ as m_p, A and P_0 are given. and g is gravitational acc. constant.

To find Work, need to find V_1 and V_3 and then apply $${}_1W_3 = \overset{=0}{\cancel{{}_1W_2}} + {}_2W_3 = \int_2^3 P\,dV$$

${}_1W_2 = 0$ since Volume is constant from state ① to ②. V_2 is same as V_1 which is found above. so need to find V_3. since P_3 is found, lookup B.1.1 for corresponding v_g. so $\boxed{V_3 = m v_{g_3}}$ — ③ →

now that V_2 and V_3 are known, we can find work



$$ {}_2W_3 = \int_2^3 P\,dV $$

$$ \boxed{{}_2W_3 = P_{left}\left(V_3 - V_2\right)} $$

using eq ① and ③ and ②, above can be written as

$$ \boxed{{}_2W_3 = \left(\frac{m_p g}{A} + P_0\right)\left(m v_{g_3} - m\left(v_{f_1} + x_1 v_{fg_1}\right)\right)} \quad ④ $$

now to find heat transfer during the process, use the first law of thermodynamics. note that $\Delta PE = 0$ and $\Delta KE = 0$.

hence $U_3 - U_1 = {}_1Q_3 - {}_1W_3$

but ${}_1W_3 = {}_2W_3$ and this is found from ④ above.

so need to find U_3 and U_1.

we can find u_f, u_{fg} in state ① from table B.1.1 and since x_1 is given, we find u_1, and since mass is known, we find U_1:

$$ \boxed{U_1 = m u_1 = m\left(u_{f_1} + x u_{fg_1}\right)} $$

similarly find $u_3 = u_{g_3}$ from table B.1.1, by looking up v_g for $P_3 = P_{left}$. and since mass is constant, then

$\boxed{U_3 = m u_{g_3}}$, then solve for ${}_1Q_3$ →

so $${}_1Q_3 = (U_3 - U_1) + {}_2W_3$$

$$\boxed{{}_1Q_3 = \left[m\,u_{g_3} - m(u_{f_1} + x\,u_{fg_1})\right] + \underbrace{{}_2W_3}_{\text{from eq ④}}}$$

—— ⑤

Numerical

use equation ①

$$V_1 = m(v_{f_1} + x_1 v_{fg_1}).$$

from table B.1.1, for $T_1 = 100°C$, $v_{f_1} = 0.001044\ m^3/kg$.

$v_{fg_1} = 1.67185\ m^3/kg$ x_1 is given as 0.2, $m = 5kg$.

so $V_1 = 5(0.001044 + 0.2(1.67185)) = \boxed{1.67707\ m^3}$

now find P_{left} using eq. ②

$$P_{left} = \frac{m_p g}{A} + P_o = \frac{(75)(9.81)}{24.5\times10^{-4}} + 100\times10^3 = 400306\ Pa$$
$$= \boxed{400.306\ kPa}$$

to find work, use eq ④

$${}_2W_3 = P_{left}\left(m v_{g_3} - m(v_{f_1} + x\,v_{fg_1})\right).$$

lookup v_{g_3}. from B.1.2, for entry $P = P_{left} = 400.306\ kPa$ use entry for $P = 400\ kPa$ as very close.

$\Rightarrow$ $v_{g_3} = 0.46246\ m^3/kg$.

so $${}_2W_3 = 400.306\times10^3\left(5(0.46246) - 5(0.001044 + 0.2(1.67185))\right)$$

$$= 254286.3\ J = \boxed{254.286\ kJ}$$

⟶

now to find heat transfer.

use eq ⑤ shown in the steps section.

$${}_1Q_3 = m\left(u_{g_3} - (u_{f_1} + x\, u_{fg_1})\right) + {}_2W_3$$

lookup u_{g_3} from B.1.2, for entry at $P = P_{left} = 400\ \text{kPa}$

$$\Rightarrow \boxed{u_{g_3} = 2553.55 \times 10^3\ \text{J/kg}}$$

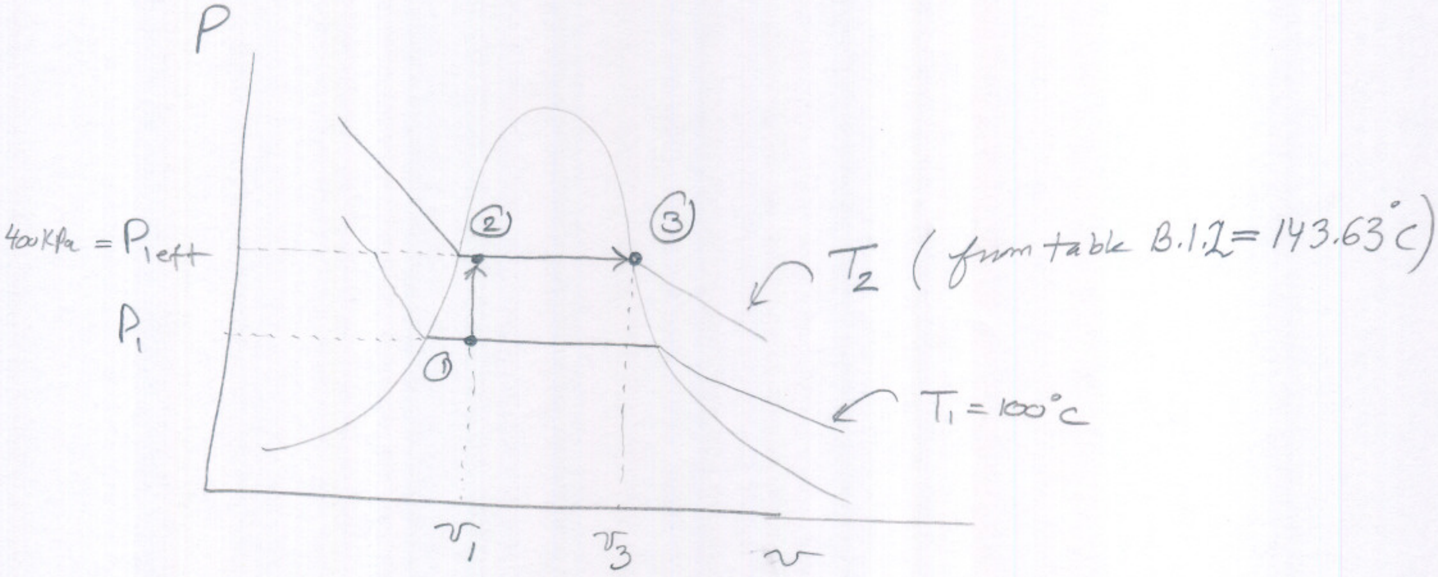
lookup u_{f_1}, u_{fg_1} from B.1.1 for entry at T=100°C.

$$\Rightarrow \boxed{\begin{aligned} u_{f_1} &= 418.91 \times 10^3\ \text{J/kg} \\ u_{gf_1} &= 2087.58 \times 10^3\ \text{J/kg} \end{aligned}}$$

$$\text{hence} \quad {}_1Q_3 = 5\left(2553.55 \times 10^3 - \left(418.91 \times 10^3 + 0.2\,(2087.58 \times 10^3)\right)\right)$$

$$= \boxed{8{,}585{,}620\ \text{J} \approx 8.585\ \text{MJ}}$$

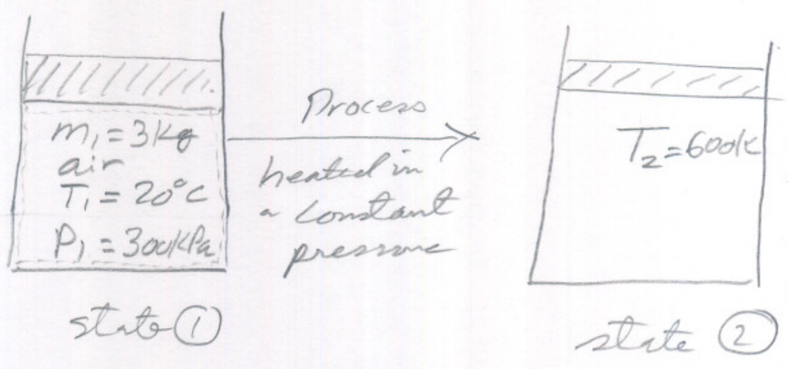
now show P-v diagram



problem 5-94

10/10

statment



find heat transfer.

Assumptions

- frictionless piston.
- ideal process
- ideal gas conditions
- pure substance
- control mass. so $m_2 = m_1$
- table A.7 entries are Linear (so can interpolate).

Laws

$U_2 - U_1 + \Delta PE + \Delta KE = {}_1Q_2 - {}_1W_2$

$PV = mRT$ (assuming ideal gas)

table A.7, A.5

Steps

apply the first Law of thermodynamics

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

where $\Delta PE = 0$, $\Delta KE = 0$.

need to find ${}_1Q_2$. so need to find ${}_1W_2$ and need to find change in internal energy between state ① and ②

→

start by finding work.

Volume in state ① can be found by using ideal gas Laws

$$P_1 V_1 = m R T_1 \Rightarrow \boxed{V_1 = \frac{m R T_1}{P_1}} \quad \text{———} \ ①$$

since m, T_1, P_1 are given. R for air is from table A.5

now need to find final Volume V_2.

since mass is fixed, and T_2 is given, and constant pressure process, then

$$\boxed{V_2 = \frac{m R T_2}{P_2}} \quad \text{where } P_2 = P_1 \quad \text{———} \ ②$$

hence

$$ {}_1W_2 = \int_1^2 P\,dV = P_1 (V_2 - V_1)$$

$$= P_1 \left(\frac{m R T_2}{P_1} - \frac{m R T_1}{P_1} \right)$$

$$\boxed{{}_1W_2 = m R (T_2 - T_1)} \quad \text{———} \ ③$$

now that work is found, need to find internal energy change. so need to find u_2 and u_1

Since ideal gas, use table A.7 lookup u for air at differet T.

then

$$ {}_1Q_2 = m \overbrace{(u_2 - u_1)}^{\text{lookup in A.7 at } T_2 \text{ and } T_1} + {}_1W_2 \quad \text{———} \ ④$$

$\longrightarrow$

Numerical

find V_1 using eq ①

$V_1 = mR\frac{T_1}{P_1}$.   where $m = 3kg$, $R = 0.287\times10^3$ J/kg-K

$T_1 = 273.15 + 20 = 293.15$ K

$P_1 = 300\times10^3$ Pa.

so $V_1 = 3(0.287\times10^3)\frac{293.15}{300\times10^3} = \boxed{0.84134\ m^3}$

find V_2 from eq ②

$V_2 = mR\frac{T_2}{P_2} = 3(0.287\times10^3)\frac{600}{300\times10^3} = \boxed{1.722\ m^3}$

find ${}_1W_2$ from eq ③

${}_1W_2 = mR(T_2 - T_1) = 3(0.287\times10^3)(600 - 293.15)$

$= \boxed{264197.85\ J = 264.197\ KJ}$

from table A.7, $\boxed{u_2 = 435.10\times10^3\ J/kg.}$

u_1 = need to interpolate (Assume linear.)

$T = 290$ $u = 207.19$

$T = 300$ $u = 214.39$

so $\frac{300 - 290}{214.39 - 207.19} = \frac{300 - 293.15}{214.39 - u_1} \Rightarrow u_1 = \boxed{209.458\times10^3\ J/kg}$

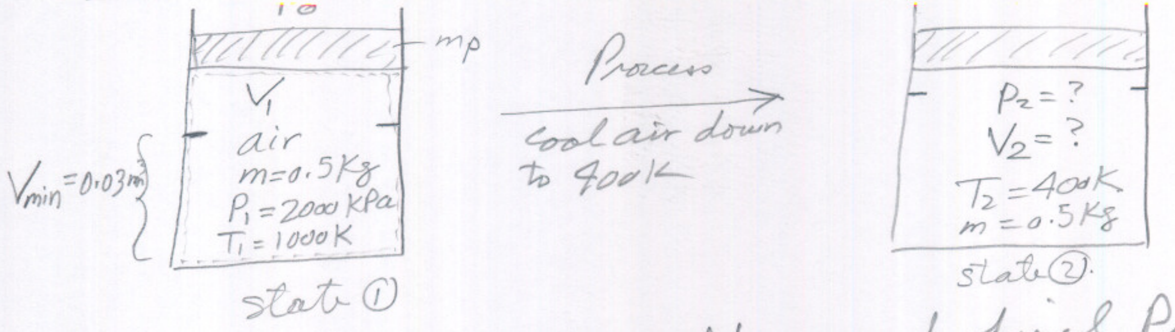
so from eq ④

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

$= 3(435.1\times10^3 - 209.458\times10^3) + 264197 = \boxed{941123J}$

problem 5.99

10/10



page of
problem
solution for
the actual
process
found)

Find final volume V_2. and final Pressure P_2

Find work and heat transfer in the process.

Assumptions

- ideal gas model for air.
- ideal process.
- Frictionless piston.
- Control mass. so $m_2 = m_1$

Laws

$$PV = mRT$$

$$(U_2 - U_1) + \Delta PE + \Delta KE = {}_1Q_2 - {}_1W_2$$ (first Law of thermodynamics)

Steps

As air cools down (by heat escaping) volume of air under piston will decrease (condensation). and so the piston will fall down. pressure of air inside will remain constant as the piston falls down. if the piston hits the stops, then the volume will ofcourse remain fixed now at V_{min}, but the pressure will start to decrease.

⟶

so there are 2 possible path the process can go. one process is for air to cool down to 400K befor the piston hits the stops, so final pressure in this case is same as initial pressure.

another posibility is that piston hits the stop while temp has not reached final temp, so that final pressure will be less than initial pressure.

To find out which process, assume that final Volume is V_{min}, and find P corresponding to this V using $PV = mRT$, since T is given. if $P < P_{left}$ then we know that it will hit the stop. The above logic is illustrated below:

Let $V_2 = V_{min}$

so $P_2 V_2 = mRT_2 \Rightarrow P_2 = \frac{mRT_2}{V_{min}}$

if $P_2 < P_{left}$ where $P_{left} = P_1$, then piston will first hit the stops. we now can find T when piston hit the stops using

$P_{1a} V_{1a} = mRT_{1a}$ where now $P_{1a} = P_{left}$ and $V_{1a} = V_{min}$.

so $$\boxed{T_{1a} = \frac{P_{1a} V_{1a}}{mR} = \frac{P_{left} V_{min}}{mR}}$$

$\longrightarrow$

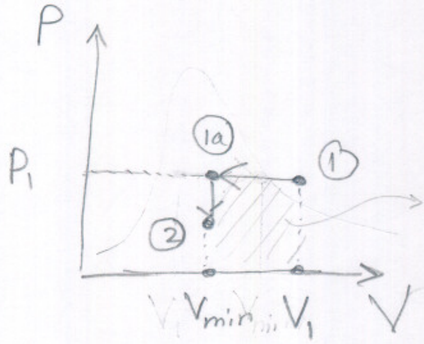
from now on, we have a constant volume process and we need to cool down the air from T_{1a} down to T_2.

so can find P_2 now using

$$P_2 V_{min} = m R T_2$$

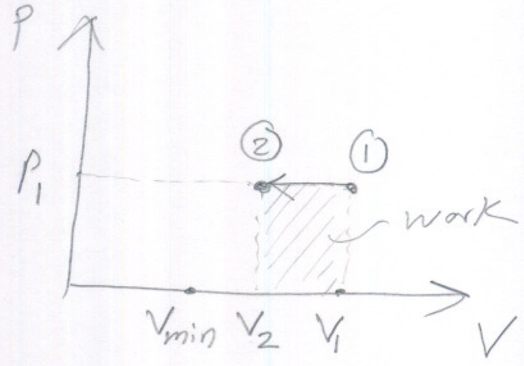
so $$\boxed{P_2 = \frac{m R T_2}{V_{min}}}$$

these 2 possibilities are shown in this diagram



piston hits stop befor T_{Final} cools down to T_{Final}.

OR



piston stop above stops when $T_2 = T_{Final}$

to find work, use

$$\boxed{{}_1W_2 = \int_1^2 P\,dV = P_{left}\,(V_2 - V_1)}$$

to find heat transfer, use

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

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

where u_2 and u_1, for ideal gas found from A.7.1

→

Numerical

$$P_2 = \frac{mRT_2}{V_{min.}}$$ but $m = 0.5\ Kg$, $T_2 = 400K$,

$V_{min} = 0.03\ m^2$

$R_{air} = 0.287 \times 10^3\ J/Kg\text{-}K$

(Table A.5)

so $$P_2 = \frac{(0.5)(0.287 \times 10^3)(400)}{0.03} = 1913.33\ KPa$$

but $P_2 < P_1$, hence piston will hit stops first. to find T_{1a}

$$T_{1a} = \frac{P_{left}\, V_{min}}{mR} = \frac{(2000 \times 10^3)(0.03)}{(0.5)(0.287 \times 10^3)} = \boxed{418.1\ K}$$

final pressure:

$$P_2 = \frac{mRT_2}{V_{min}} = \frac{(0.5)(0.287 \times 10^3)(400)}{0.03}$$

$$= \boxed{1{,}913{,}333\ \ Pa} \simeq 1913\ KPa$$

so $${}_1W_2 = P_{left}(V_2 - V_1) = 2000 \times 10^3 (0.03 - V_1)$$

but $P_1 V_1 = mRT_1$ so $V_1 = \frac{mRT_1}{P_1}$

so $${}_1W_2 = 2000 \times 10^3 \left(0.03 - \frac{0.5(0.287 \times 10^3)(1000)}{2000 \times 10^3}\right)$$

$$= \boxed{-83500\ \ J}$$

now from table A.7.1, u_1 @ $T = 1000K = 759.19 \times 10^3\ J/Kg$

u_2 @ $T = 4000\ K = 286.49 \times 10^3\ J/Kg.$

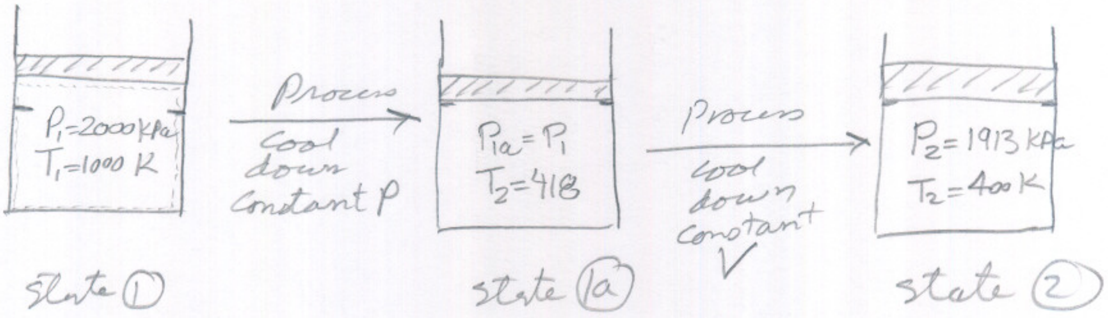
so $${}_1Q_2 = m(u_2 - u_1) + {}_1W_2$$

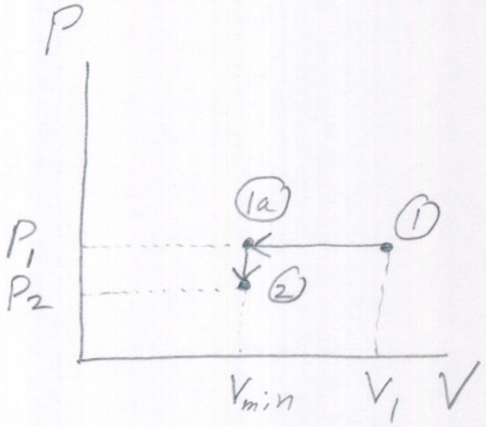
$$= (0.5)(286.49 \times 10^3 - 759.19 \times 10^3) - 83500$$

$$= \boxed{-319850\ J}$$

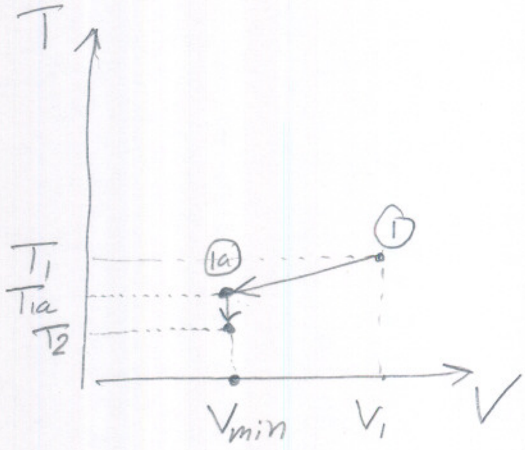
→

so actual process is





P–V diagram

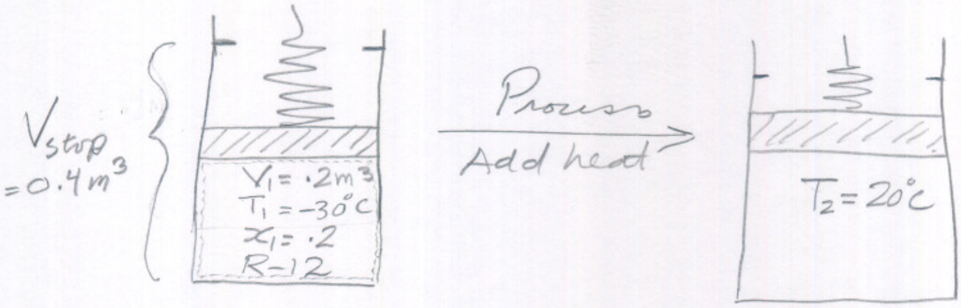


T–V diagram.

10/10

Problem 5.133

Statment



If piston sits at bottom of cylinder, then spring force balances other loads.

find mass of R-12, show P-v diagram.
find work and heat transfer.

Assumptions

Frictionless piston.
ideal process,
pure substance.
Pressure of R-12 is a linear function of Volume.
$\Delta PE = 0$, $\Delta KE = 0$, control mass. $m_2 = m_1$

Laws

$$v = \frac{V}{m}$$

$P = a + bV$ (Pressure is a linear function of V)

$$(U_2 - U_1) + \Delta KE + \Delta PE = {}_1Q_2 - {}_1W_2$$

→

steps

to find mass, use $m = \frac{V_1}{v}$

we find v (specifi volume) from table B.3.1 (we know it is in mixed phase liquid-vapor) since x is defined.

lookup v_f, v_{fg}. then

$$\boxed{m = \frac{V_1}{v_1} = \frac{V_1}{v_f + x\, v_{fg}}} \text{ ——— } ①$$

As R-12 is heated, it is possible that it will reach T_{Final} befor piston hits the stops. it also possible that it will hit the stops befor reaching final T, in which case pressure will continoue to increase but volume will be constant.

So need to find which process will occure.

To find out, we assume that final volume is V_{stop}, and find T. if found $T < T_{Final}$ then we know that piston will hit the stop.

So need to find P_{Left}. we are not given the spring constant nor mass of piston. so can't use forces balance on piston to find P_{left}.

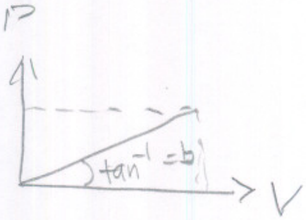
So assume that P is a linear function of Volume →

let $P = a + bV$

need to determine a, b parameter.

we are told that when $V=0$ (bottom), $P=0$

then this means $a=0$.



so $\boxed{P = bV}$

Can find slop 'b' by finding P in state ①.

from table B.3.1, look up P_1 for T_1.

so $\boxed{b = \frac{P_1}{V_1}}$ since V_1 is given.

So when $V = V_{stop} \Rightarrow \boxed{P_{stop} = \left(\frac{P_1}{V_1}\right) V_{stop}}$ ——— ②

now need to find T at this pressure. need another independent property so need to find v_{stop}.

$\boxed{v_{stop} = \frac{V_{stop}}{m}}$ ——— ③

so now look up table B.3.1, for P_{stop}, and check if $v_f < v_{stop} < v_g$, if so find T_{stop}.

if $T_{stop} < T_{Final}$, then piston will hit stop.

but if $v_{stop} > v_g$, then must use table B.3.2 to find T_{stop}.

once we decide if $T_{stop} < T_{Final}$, then the final process will be constant Volume $= V_{stop}$, and knowing T_2, we can find P_2 from Table B.3.1 or B.3.2

⟶

now ${}_1W_2 = {}_1W_{1a}$

where state ⓵a is when piston hits the stop.

$${}_1W_2 = \int_1^{1a \leftarrow \text{stop state}} P\,dV = \boxed{\frac{1}{2}(P_1 + P_{stop})(V_{stop} - V_1)} \text{ — ④}$$

to find heat transfer:

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

so $${}_1Q_2 = (U_2 - U_1) + {}_1W_2.$$

$$\boxed{{}_1Q_2 = m(u_2 - u_1) + {}_1W_2} \text{ — ⑤}$$

u_1 is found from table B.3.1 lookup.

u_2 is found from table B.3.1 or B.3.2 Lookup depending if final phase is mixed phase or Superheated. To decide, we know $\boxed{v_2 = \frac{V_{stop}}{m}}$ and we know T_2. so lookup B.3.1 and if $v_2 > v_g$ then use B.3.2

Numerical

from equation ①

$$m = \frac{V_1}{v_f + x\,v_{fg}}.$$

from table B.3.1, $v_f = 0.000672$ m³/kg.
$v_{fg} = 0.15870$ m³/kg.
at $T = -30°c$.

$$m = \frac{0.2}{0.000672 + 0.2(0.1587)} = \boxed{6.17056 \text{ kg}}$$

from eq ② $P_{stop} = \left(\frac{P_1}{V_1}\right)V_{stop}$. from B.3.1, $\boxed{P_1 = 100.4 \text{ KPa}}$

so $P_{stop} = \left(\frac{100.4 \times 10^3}{0.2}\right)0.4 = \boxed{200.8 \text{ KPa}}$ ⟶

from eq ③

$$v_{stop} = \frac{V_{stop}}{m} = \frac{0.4}{6.17056} = \boxed{0.06482 \quad m^3/Kg}$$

looking at B.3.1, I see that for P between 182.6 and 219.1 KPa, v_{stop} found above is still between v_f, v_g for either entry. so this means when piston hits stop, R-12 is in mixed-phase. so can use B.3.1.

we see that $T_{stop} < \underset{\searrow \; 20°C}{T_{Final}}$, so this means

we have a 2 path process.

to find Work, from eq ④

$$_1W_{stop} = \frac{1}{2}\left(P_1 + P_{stop}\right)\left(V_{stop} - V_1\right)$$

$$= \frac{1}{2}\left(100.4 + 200.8\right)\times10^3\left(0.4 - 0.2\right)$$

$$\boxed{\text{Work} = 30.12 \quad KJ}$$

to find u_1, from table B.3.1. $u_f = 8.79$ KJ/Kg, $u_{fg} = 149.40$ KJ/Kg.

so $u_1 = u_f + x\,u_{fg} = 8.79\times10^3 + (.2)(149.4\times10^3)$

$$= \boxed{38.67 \quad KJ/Kg}$$

to find u_2, first determine which table to use.

$v_2 = v_{stop} = 0.06482$ m^3/Kg. found above.

so from table B.3.1, at T = 20°C, we see that

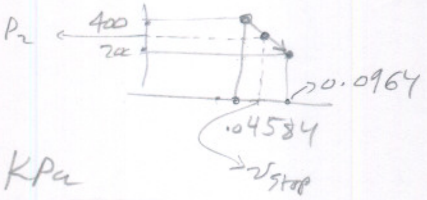
$v_2 > v_g \Longrightarrow$ $\boxed{\text{Superheated phase}}$ →

so we know $\left(\overset{\nearrow 20^\circ C}{T_2}, \overset{\nearrow 0.06482}{v_2}\right)$. and we know it is in super heated phase.

looking at B.3.2 we see that for $T_2 = 20^\circ c$, that Block for $P = 200\ kPa$ has $v = 0.09642\ m^3/Kg$. and Block for $P = 400\ kPa$ has $v = 0.04584\ m^3/Kg$.

so it is somewhere in between these.

interpolate:



$$\frac{(400-200)\,KPa}{0.0964-0.04584} = \frac{(400-P_2)\,KPa}{0.06482-0.04584}$$

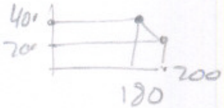
so $$\frac{(200\times10^{3})(0.06482-0.04584)}{0.0964-0.04584} = (400-P_2)$$

so $P_2 = 324.9\ kPa$

to find u_2. interpolate.

$P = 400\ KPa$ $\quad u = 180.57\ KJ/Kg$ at $T = 20^\circ c$

$P = 200\ KPa$ $\quad u = 202.28\ KJ/Kg$ at $T = 20^\circ C$



so $$\frac{400-200}{202.28-180.57} = \frac{400-324.9}{u_2-180.57}$$

$$\Rightarrow \boxed{u_2 = 188.72\ KJ/Kg.}$$

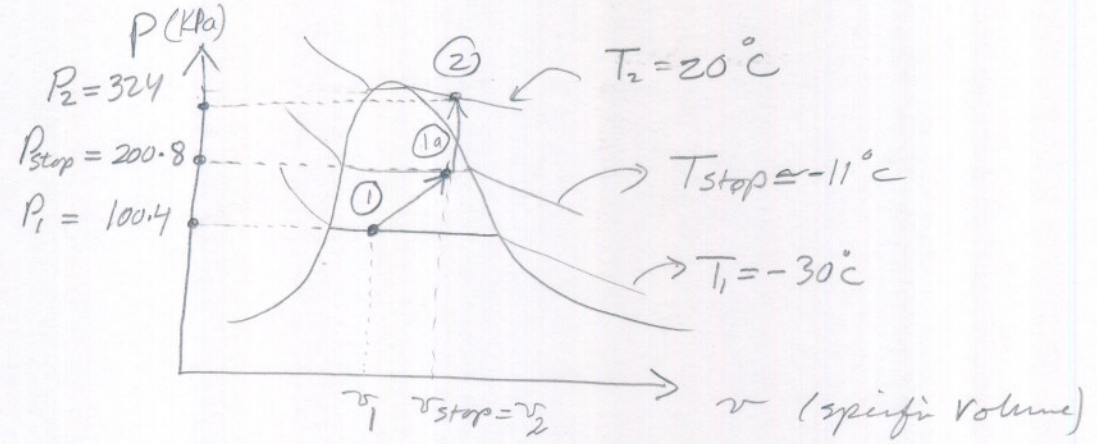
so from eq ⑤

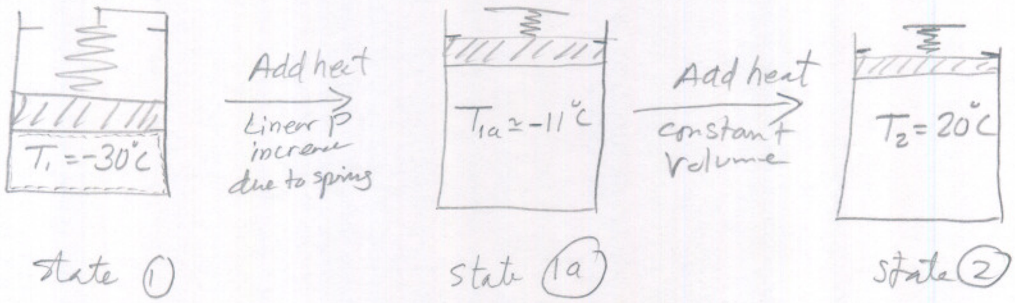
$${}_1Q_2 = m(u_2-u_1) + {}_1W_2 = (6.17055)(188.72\times10^3 - 38.67\times10^3) + 30.12\times10^3$$

$$= \boxed{956.011\ KJ}$$

$\longrightarrow$

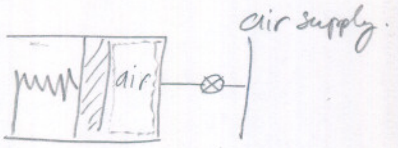
to show P-v diagram





Problem 4.39 5/5

statment



Air pressure is linear with Volume.

$P = A + BV.$

when $P_1 = 150\,kPa$, $V_1 = 1L = 10^{-3}\,m^3$

when $P_2 = 800\,kPa$, $V_2 = 1.5\,L = 1.5 \times 10^{-3}\,m^3$

find work done by air

Assumptions

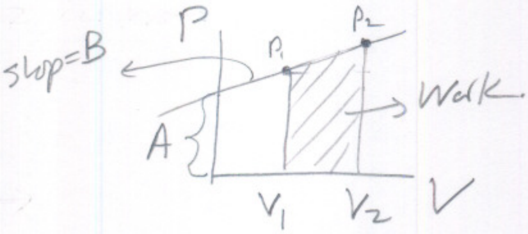
ideal process.

Laws

$$_1W_2 = \int_1^2 P\,dV$$

Steps

since P is liner in V, then it will look like



then $_1W_2 = \int_1^2 P\,dV$

$$\boxed{_1W_2 = \frac{(P_1 + P_{12})}{2}(V_2 - V_1)}$$

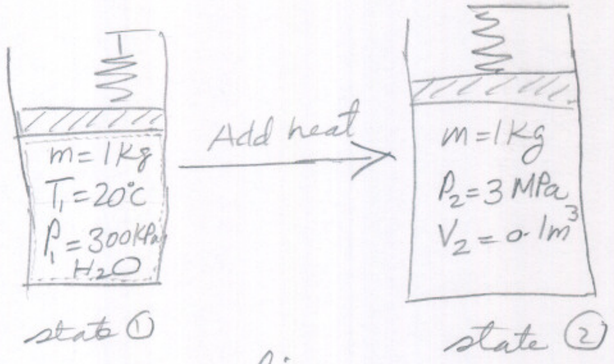
Numerical

$$_1W_2 = \frac{(150+800)10^3}{2}(1.5-1)10^{-3} = \boxed{237.5\ J}$$

Problem 4.42

5/5

statment



spring is linear

Find

a) T_2

b) Plot P–v diagram

c) Find Work in the process.

Assumptions

control mass. $m_2 = m_1$

ideal process.

pure substance.

spring is linear implies P changes linearly with V

Laws

$$ {}_1W_2 = \int_1^2 P\,dV = \left(\frac{P_2 + P_1}{2}\right)(V_2 - V_1) \quad \text{for linear } P(V). $$

$$ v = \frac{V}{m} $$

steps

a) find v_2 from $\boxed{v_2 = \frac{V_2}{m}}$ ——— ①

so in state 2, we know (P_2, v_2). hence can determine phase, and use the appropriate B.1.* table to find T_2.

b) in state ①, we are told water is liquid. so use compressed liquid table B.1.4, using given (P_1, T_1) to find v_1. now can plot P–v diagram →

c) To find work. since we found v_1 in part b) then we find $\boxed{V_1 = v_1 m}$. then use

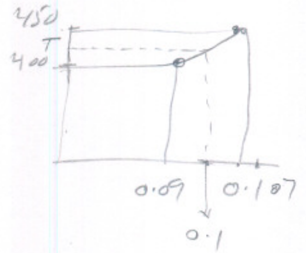
$$\boxed{{}_1W_2 = \int_1^2 P\,dV = \frac{1}{2}(P_2+P_1)(V_2-V_1)}$$

Numerical

a) from eq ①, $v_2 = \frac{V_2}{m} = \frac{0.1}{1} = \boxed{0.1\ m^3/Kg}$

so we have (P_2, v_2) or $(3\ MPa, 0.1)$. we see from table B.1.1 that for $v_g = 0.1\ m^3/Kg$, then $P \approx 1.9\ MPa$. hence since $P_2 > 1.9\ MPa$, in state ②, water is in $\boxed{\text{super heated phase}}$ so use B.1.3. using block for $P = 3MPa$

use intepolation.



$T = 400 \quad v = 0.09736$

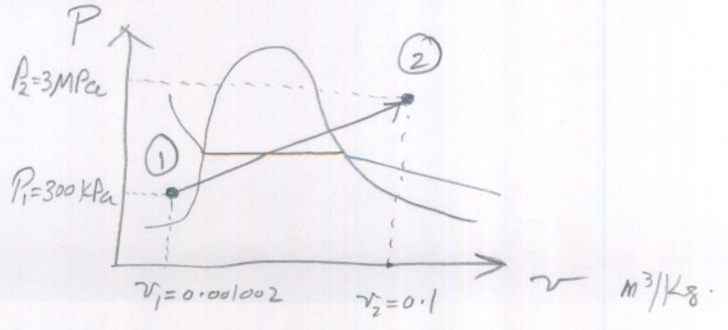
$T = 450 \quad v = 0.10787$

so $$\frac{450-400}{0.10787-0.09936} = \frac{450-T_2}{0.10787-0.1}$$

so $\boxed{T_2 = 403.76\ °C}$ this is final T.

b) lookup using table B.1.4. (P_1, T_1) or $(300\ KPa, 20°C)$

$v_1 = \boxed{0.001002}\ m^3/Kg$.



c) $V_1 = v_1 m$

$$= (0.001002)(1) = \boxed{0.001002 \ m^3}$$

so we have $V_1 = 0.001002 \ m^3$

$V_2 = 0.1 \ m^3$

$P_1 = 300 \ KPa$

$P_2 = 3 \ MPa.$

$${}_1W_2 = \int_1^2 P\,dV = \left(\frac{P_2 + P_1}{2}\right)(V_2 - V_1)$$

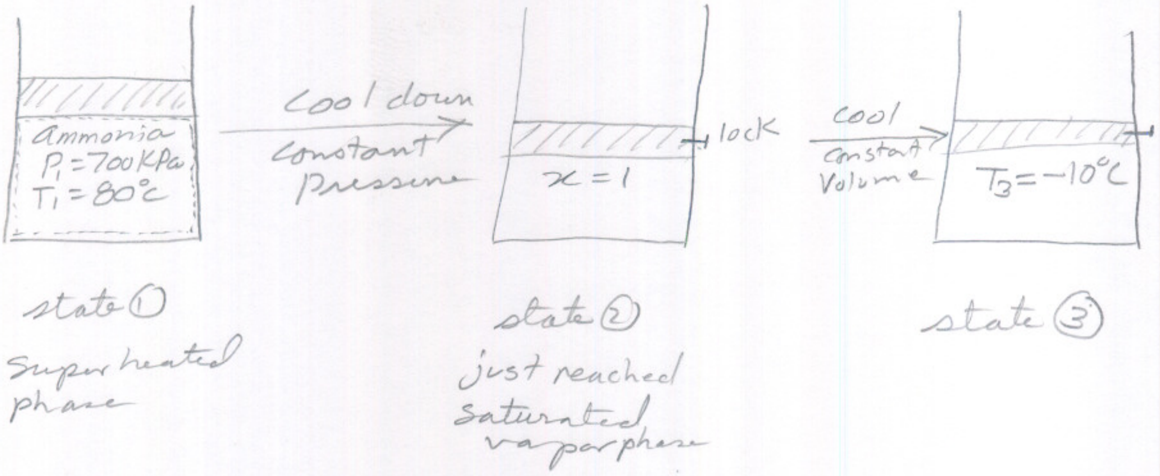
$$= \left(\frac{3\times10^6 + 300\times10^3}{2}\right)(0.1 - 0.001002)$$

$$= \boxed{163.346 \quad KJ}$$

Problem 4.66

4/5

statment



Find work in the process.

Assumptions

- in state ②, $x=1$ since just entered saturated vapor phase from superheated phase.
- ideal process.
- frictionless piston.
- control mass.

Laws

$$ {}_1W_2 = \int_1^2 P\,dV = P(V_2 - V_1) $$ for Constant pressure

No work from state ② → ③ since Volume is fixed.

Steps

from table B.2.2 (superheated amonia) using (P_1, T_1), lookup v_1.

from table B.2.1 (saturated ammonia) lookup $v_2 = v_g$ at P_1 (since same pressure).

hence $\boxed{{}_1W_2 = P_1(v_2 - v_1)}$ ← speific work. or work per unit mass since mass is constant in both states →

Numerical

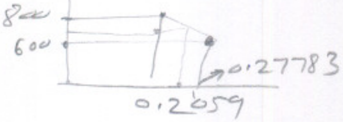
from table B.2.2, using (P_1, T_1) or $(700\,kPa, 80^\circ C)$,

interpolation:

$P = 600\ kPa$, $v = 0.27783\ m^3/kg$. (for $T = 80^\circ C$)

$P = 800\ kPa$, $v = 0.20590\ m^3/kg$. ($T = 80^\circ C$)

so $$\frac{800 - 600}{0.27783 - 0.2059} = \frac{800 - 700}{v_1 - 0.2059}$$



so $$\boxed{v_1 = 0.241865\ m^3/kg}$$

Now, from B.2.1, lookup v_g at ($P_1 = 700\ kPa$).

interpolation:

$P = 615.2\ kPa$ $v_g = 0.20541\ m^3/kg$.

$P = 728.6\ kPa$ $v_g = 0.17462\ m^3/kg$

so $$\frac{728.6 - 615.2}{.20541 - 0.17462} = \frac{728.6 - 700}{v_g - 0.17462}$$

so $$\boxed{v_2 = v_g = 0.182385\ m^3/kg}$$

✓

so, $${}_1W_2 = P_1(v_2 - v_1) = 700 \times 10^3 (0.182385 - 0.241865)$$

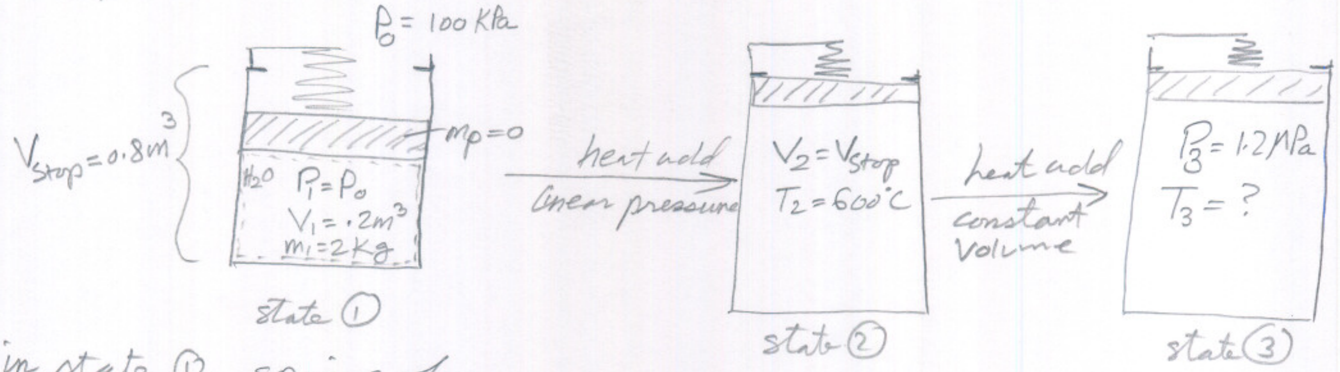
$$= \boxed{-41.636\ KJ/kg}$$

since specific work is negative, this means that work is being done on system.

5/5

Problem 4.110

statment



in state ①, spring force = 0.
piston is massless.
spring is lined.
Find T_3 and Work done during process. show P-V diagram

Assumptions

Frictionless piston.
ideal process.
pure substance.
Control mass. so $m_1 = m_2 = m_3$

Laws

$$ {}_1W_2 = \int_1^2 P\,dV = \frac{1}{2}(P_1 + P_2)(V_2 - V_1) \text{ for liner } P(V). $$

$$ v = \frac{V}{m} $$

water steam tables

$v > v_g \Rightarrow$ superheated phase

Steps

to find T_3, we need 2 independent properties in state ③. we are given one (P_3). so need to find specific volume v_3 to be able to find T_3.

since mass is constant, then

$$ \boxed{v_3 = \frac{V_{stop}}{m}} \text{ ——— } ① $$

$\longrightarrow$

now we can find T_3 by looking up appropriate steam table B.1.x.

To find work, we need to find work from state ① to ② only, since there is no volume change between states ② and ③.

so $${}_1W_2 = \int_1^2 P\,dV.$$

Since spring force is linear, then

$$ {}_1W_2 = \frac{1}{2}\left(P_1+P_2\right)\left(V_2-V_1\right) $$

we are given P_1, $V_2=V_{stop}$, V_1. so need to only find P_2.

in state ② we have 2 independent properties (T, v). so can find P_2.

$\boxed{v_2 = \frac{V_{stop}}{m}}$. now can find P_2 from B.1.x tables.

so $\boxed{{}_1W_2 = \frac{1}{2}\left(P_1+P_2\right)\left(V_2-V_1\right)}$ —— ②

Numerical

using eq ① $\quad v_3 = \frac{V_{stop}}{m} = \frac{0.8\ m^3}{2\ kg} = \boxed{0.4\ m^3/kg}$

so we have $(P_3, v_3) = (1.2\ MPa, 0.4)$. from B.1.1, we see that for $P = 1.3\,MP$, $\boxed{v_3 > v_g}$. $\Rightarrow$ $\boxed{\text{Super heated Phase}}$

$\longrightarrow$

so use table B.1.3 (super heated water vapor).

interpolation: $T = 700^\circ C$ $v = 0.37294\ m^3/kg$

$T = 800^\circ C$ $v = 0.41177\ m^3/kg$.

so $$\frac{800-700}{0.41177-0.37294} = \frac{800-T_3}{0.41177-0.4} \Rightarrow \boxed{T_3 = 769.688\ ^\circ C}$$

using eq ②.

$${}_1W_2 = \frac{1}{2}(P_1+P_2)(V_2-V_1) \quad ; \quad V_2 = 0.8\ m^3,\ V_1 = 0.2\ m^3$$

First find P_2. in state ② we have $(T, v) = (600^\circ, .4)$.

so from table B.1.1, we see that for $v_g \approx .4$,

$T < 600^\circ C$. so in super heated phase.

so looking at table B.1.3

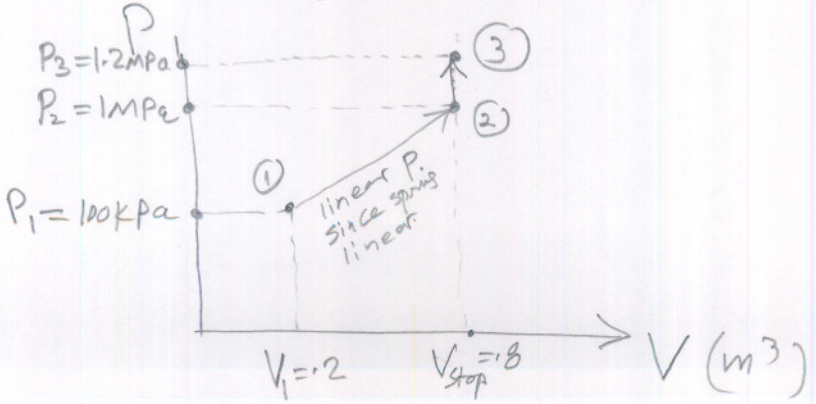
we see that for $P = 1\ MPa$, at $T = 600^\circ$, $v = 0.40109\ m^3/kg$

so use $P_2 = 1\ MPa$ as good approximation.

hence $${}_1W_2 = \frac{1}{2}(100\times10^3 + 1\times10^6)(0.8-0.2)$$

$$= \boxed{330\ KJ}$$

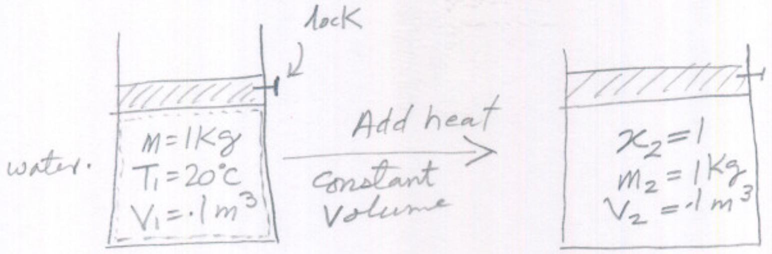
since Work is +ve, this means system is doing the work itself.



Problem 5.40

5/5

Statment



heat is added to a control volume/control mass untill all water has just evaporated. Find T_2 and amount of heat transfer.

Assumptions

Control mass. so $m_2 = m_1$

Control Volume. so $V_2 = V_1$

pure substance. ideal process.

$d(PE) = 0, \quad d(KE) = 0.$

Laws

- Steam tables B.1.1
- first Law of thermodynamics $d(U) + \overset{=0}{\cancel{d(PE)}} + \overset{=0}{\cancel{d(KE)}} = \delta Q - \delta W$
- $v = \dfrac{V}{m}$
- if at vapor saturation line, then $x = 1$ and $v = v_g$.

Steps

To find T_2, need 2 independent variables in state ②. since control mass and control volume, then

$$\boxed{v_2 = \frac{V_1}{m_1}} \text{ — ①}$$ as V_1, m_1 are given.

since we are told that in state ②, $x_2 = 1$, then $v_2 = v_g$ then. so use table B.1.1 to find T corresponding to $v_g = v_2$. this will be T_2.

→

now, to find amount of heat.

since Work is zero (as no change in Volume) then

$$\boxed{m(u_2-u_1) = {}_1Q_2} \text{ —— } ②$$

we can find u_1 from table B.1.1. look up u_f, u_{fg} for $(T_1 = 20\,^\circ c)$.

then $u_1 = u_f + x_1 u_{fg}$.

where x_1 is found from

$$x_1 = \frac{v_1 - v_f}{v_{fg}}.$$

So

$$\boxed{u_1 = u_{f_1} + \left(\frac{v_1 - v_{f_1}}{v_{fg_1}}\right) u_{fg_1}} \text{ —— } ③.$$

in state ②, $u_2 = u_{g_2}$ at T_2 (since $x=1$).

So look up u_g in B.1.1 at $T = T_2$.

hence eq. ② becomes

$$\boxed{m\left(u_{g_2} - \left(u_{f_1} + \left(\frac{v_1 - v_{f_1}}{v_{fg_1}}\right) u_{fg_1}\right)\right) = {}_1Q_2} \text{ —— } ④$$

Numerical

eq ①: $v_2 = \frac{V_1}{m_1} = \frac{.1\ m^3}{1\ Kg} = \boxed{.1\ m^3/Kg}$

look-up B.1.1, we interpolate

$T = 210$, $v_g = 0.10441\ m^3/Kg$

$T = 215$, $v_g = 0.09479\ m^3/Kg$

$$\Rightarrow \frac{215-210}{0.10441-0.09479} = \frac{215-T_2}{0.1-0.09479}$$

$$\Rightarrow \boxed{T_2 = 212.292\,^\circ c}$$

⟶

now need to find u_{g_2}:

from same table B.1.1, interpolate to find u_g.

$T = 210^\circ C$, $u_g = 2599.44$ KJ/Kg.

$T = 215^\circ C$, $u_g = 2601.06$ KJ/Kg.

so $$\frac{215 - 210}{2601.06 - 2599.44} = \frac{215 - 212.292}{2601.06 - u_{g_2}} \Rightarrow u_{g_2} = \boxed{2600.18 \text{ KJ/Kg}}$$

now find v_1, v_{f_1}, v_{fg_1}.

$$v_1 = \frac{V_1}{m_1} = \frac{.1}{1} = \boxed{.1 \ m^3/Kg}$$

at $T_1 = 20^\circ c$, we see that $v_f < v_1 < v_g$. hence we are in mixed phase liquid-vapor in state ①.

so use B.1.1 to find u_{f_1}, u_{fg_1}.

$\boxed{u_{f_1} = 83.94 \text{ KJ/Kg}}$, $\boxed{u_{fg_1} = 2318.98 \text{ KJ/Kg}}$ at $T = 20^\circ c$

$\boxed{v_{f_1} = 0.001002 \ m^3/Kg}$ $\boxed{v_{fg_1} = 57.7887 \ m^3/Kg}$ at $T = 20^\circ C$

so apply eq ④

$$m\left(u_{g_2} - \left(u_{f_1} + \left(\frac{v_1 - v_{f_1}}{v_{fg_1}}\right) u_{fg_1}\right)\right) = {}_1Q_2$$

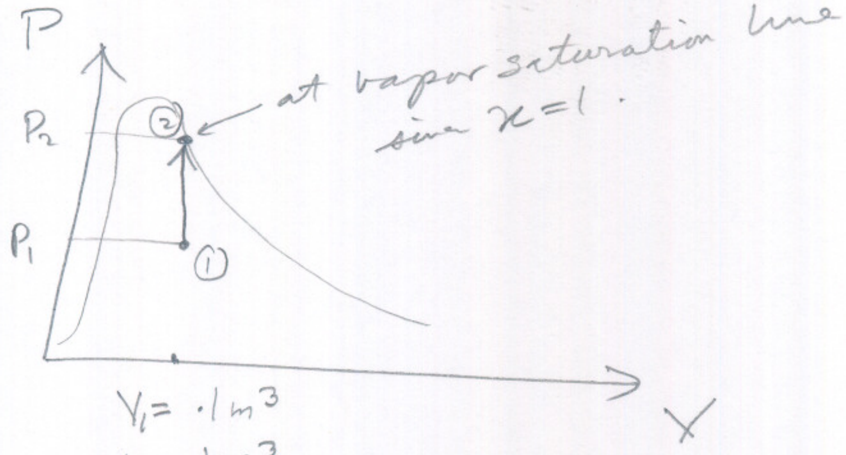
so $${}_1Q_2 = 1\left(2600.18 \times 10^3 - \left(83.94 \times 10^3 + \left(\frac{0.1 - 0.001002}{57.7887}\right) 2318.98 \times 10^3\right)\right)$$

$= 2{,}512{,}267.34$ J

$\cong \boxed{2.512 \text{ MJ}}$

→

P-V diagram



at vapor saturation line since $x=1$.

$V_1 = .1 m^3$
$V_2 = .1 m^3$