Q. 1. Assignment – 4.

$$\left[\begin{array}{ll} P_o = 0.4\ \text{MPa}, & T_o = 30^\circ C \\ v_o = 0.04792\ m^3/kg, & h_o = 205.58 \end{array}\right.$$

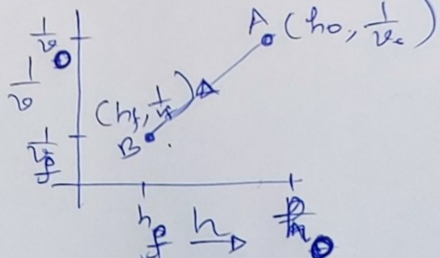
$P_f = 0.3$ Ma, $T_f = ?$

$v_f = ?$ $h_f = ?$

Assumption

[we are always in superheated regime

[$\frac{1}{v}$ & h are linearly dependent



[as Q = 0, & gas is going out from tank]

the only possibility is decrease in Temp;

from superheated steam table of Freon

$$T_f < T_o = 30^\circ$$

from table for any $T < 30^\circ c$

$$h_f < h_o$$

$$\& \quad v_f > v_o \Rightarrow \frac{1}{v_f} < \frac{1}{v_o}$$

eqn. of discharging of a tank. (refer solution of Q.2)

$$\cancel{Q} = (P_o - P_f)\forall + \forall \int \frac{1}{v_e} dh_e$$

0   → −ive

$$\Rightarrow P_o - P_f = -\int \frac{1}{v_e} dh_e$$

LHS. 0.1 MPa   R.H.S. = (−) (−) area under curve AB

$$= (-)(-)(h_o - h_f)\left(\frac{\frac{1}{v_f} + \frac{1}{v_o}}{2}\right)$$

Let us guess, $T_f = 20^\circ C$ at $P = 0.3$ MPa

for which $v_f = 0.06273\ m^3/kg$ $h_f = 200.64$ kJ/kg

hence RHS. = 90.86 kPa = 0.0908 MPa

LHS ≈ RHS

one can be more precise

hence mass entered in tank.

$m_f - m_o =$ (.05/.04797)-(.05/.06273)= 0.245kg

0.25279

Q2

from energy eqn:

$$\frac{dE}{dt} = -\dot{m}_e h_e + \dot{Q}$$

mass balance

$$\frac{dm}{dt} = -\dot{m}_e$$

$$dm = -\dot{m}_e dt$$

$$\Rightarrow \int d(mu) = \int -\dot{m}_e h_e dt + \int \dot{Q} dt$$

enthalpy of gas at exit at time t ← $\boxed{h_e = \text{enthalpy of gas inside tank at instant } t}$

$$\Rightarrow m_f u_f - m_o u_o = \int h_e (-\dot{m}_e) dt + Q$$

$$\Rightarrow m_f u_f - m_o u_o = \int h_e dm + Q$$

$$\Rightarrow Q = m_f u_f - m_o u_o - \int h_e dm$$

$$d(h_e m) = h_e dm + m dh_e$$

$$\Rightarrow h_e dm = d(h_e m) - m dh_e$$

$$\Rightarrow Q = m_f u_f - m_o u_o - \int \{ d(h_e m) - m dh_e \}$$

$$\Rightarrow Q = m_f u_f - m_o u_o - \int d(h_e m) + \int m dh_e$$

$$\Rightarrow Q = m_f u_f - m_o u_o - (m_f h_f - m_o h_o) + \int m dh_e$$

$$Q = m_o(h_o - u_o) - m_f(h_f - u_f) + \int m\,dh_e$$

$$Q = m_o(P_o v_o) - m_f P_f v_f + \int m\,dh_e$$

$$Q = P_o(m_o v_o) - P_f(m_f v_f) + \int m\,dh_e$$

$$Q = P_o \forall - P_f \forall + \int \frac{\forall}{v}\,dh_e$$

$$\boxed{Q = (P_o - P_f)\forall + \forall\left(\int \frac{1}{v}\,dh_e\right)}$$

at $T = 400^\circ C$

P	v	$\frac{1}{v}$	h_e
50 bar			
⋮			
20 bar			

(from superheated steam table)

↓

numerical integration

↓

see next page

$$Q = (50-20)(0.1)(1) + 0.607 \text{ MJ}$$

(10) factor to convert into MJ

$$\boxed{Q = 3.607 \text{ MJ}}$$ Ans

$\forall \int^{1\,m^3} \left(\frac{1}{v}\right) dh$

$T = 400^\circ C$

P_o	v	$\frac{1}{v}$	h
50 bar	0.057		3198.3
45	0.064		3207.1
40	0.073		3215.7
38	0.077		3219.1
36	0.082		3222.5
34	0.087		3225.9
32	0.092		3229.2
30	0.099		3232.5
28	0.106		3235.8
26	0.115		3239
24	0.125		3242.3
22	0.139		3245.5
20	0.151		3248.7

Area under curve

$$\int \frac{1}{v}\,(dh)$$

$$= \sum_j \left\{\frac{\left(\frac{1}{v}\right)_j + \left(\frac{1}{v}\right)_{j+1}}{2}\right\}\left(h_j - h_{j+1}\right)$$

$$= 607.525 \left(\frac{kg}{m^3}\,\frac{kJ}{kg}\right)$$

$$= 0.607 \text{ MJ}$$

Q.3 $m_0 = \frac{V}{v} = \frac{1}{v} = \frac{1}{1.694}$ kg $= 0.59$ kg

$u_0 = h_0 - P_0 v_0 = 2506$ kJ/kg (1 Ma, 200°C) superheated

tank charging eqn. $h_{supply} = 2826.8$ kJ/kg

$$(m_f - m_0) h_{supply} = m_f u_f - m_0 u_0 - \cancel{Q}^{\,0} \quad \text{— (a)}$$

(insulated)

in the above eqn. we have two unknowns

$\boxed{m_f \;\&\; u_f}$ → they are co-related with eqn of state, which is not known to us. Hence we have to adopt trial method.

we have to start guessing temp & have to check that for which temp. (at 1 Ma) we get L.H.S = R.H.S for eqn (a)

Anyway it is given in the problem that we have to prove that $T_f = 290°C$

so at 1 Ma, 290°C we have super heated steam.

via interpolation
$v_f = 0.25279$ m³/kg
$h_f = 3029.57$ m³/kg

hence $u_f = h_f - P_f v_f = 2776.78$ kJ/kg

so $L.H.S = \left(\frac{1}{0.25279} - 0.59\right) 2826.8$ kJ

$= 9519.8$ kJ

$$RHS = \left(\frac{1 \times 2776.78}{0.25279} - (0.59) 2506\right) \text{kJ}$$

$= 9508$ kJ/kg

LHS $\approx$ RHS

one can be more precise

hence mass entered in tank.

$$m_f - m_0 = \frac{1}{0.25279} - 0.59 = 3.366\,\text{kg}$$

Q4.

we are assuming it constant

$$h_e(m_0 - m_f) = Q - (m_f u_f - m_0 u_0)$$

$T = 120°C, \quad P_{sat} = 1.9854$ bar

$v_f = 0.001060 \, m^3/kg \quad v_g = 0.8915 \, m^3/kg$

$h_f = 503.72 \, kJ/kg \quad h_g = 2706 \, kJ/kg$

$$m_{liq.} = \frac{0.05}{0.0010606} = 47.14 \, kg \quad m_g = \frac{0.15}{0.8915}$$

$$= 0.168 \, kg$$

$$X_0 \text{ (initial quality)} = \frac{0.168}{47.308} = 3.55 \times 10^{-3}$$

$$v_0 = \frac{m}{m_0} = \frac{0.2}{47.308} = 4.2276 \times 10^{-3} \, m^3/kg$$

$$h_0 = h_g X + h_f(1 - X)$$
$$= 511.54 \, kJ/kg.$$

$$u_0 = 511.54 \times 10^3 - 1.9854 \times 10^5 \times 4.2276 \times 10^{-3}$$
$$= 510.7 \, kJ/kg.$$

final state 1 bar 100°C

$v_f = 1.696 \, m^3/kg \quad h_f = 2676.2 \, kJ/kg$

$$u_f = 2676.2 \times 10^3 - 1 \times 10^5 \times 1.696$$
$$= 2506.6 \, kJ/kg$$

Assumption

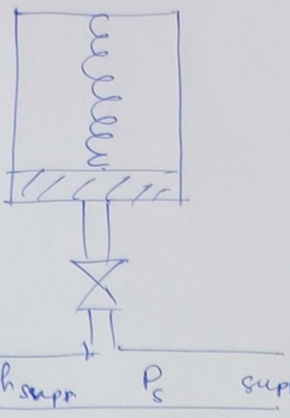
$$h_e = \frac{h_0 + h_f}{2} = 2691.1 \, kJ/kg$$

$m_0 - m_f = 47.19 \, kg.$

$Q = 150.86 \, MJ$

Q. 5.

empty tank, $\underline{m_0 = 0}$



$h_i = h_{supply}$

$$\frac{dm}{dt} = \dot{m}_i$$

$$\int \dot{m}_i dt = \Delta m$$

we consider → lower part of tank (below piston) as our CV (note down CV boundary is moving) Let's dont care whether we can say it CV in strict sense or not)

first law.

Insulated.

$$\cancel{\dot{m}_e}(h_e) - \dot{m}_i h_i = \cancel{\dot{Q}} - \dot{W}_s - \frac{dE}{dt}$$

no exit

shaft work.

⇒

$$-\dot{m}_i h_i + \dot{W}_s = -\frac{dE}{dt}$$

$$\Rightarrow -\dot{W}_s + \dot{m}_i h_i = \frac{dE}{dt}$$

⇒

$$\int -\dot{W}_s dt + h_i \int \dot{m}_i dt = E_f - E_i$$

$$-\frac{1}{2} k x_f^2 + h_i (\Delta m) = m_f u_f - \cancel{m_0 u_0}$$

$$\Rightarrow \boxed{m_f u_f + \frac{1}{2} k x_f^2 = h_i m_f}$$

$$\Rightarrow m_f u_f + \frac{P_f V_f}{2} = h_i m_f$$

$$\int \dot{W}_s dt = \frac{1}{2} k x_f^2$$

(x is compression)

$\int \dot{W}_s dt$ = +ive as our gas is working on spring.

(x_f is final compression in spring)

from force balance

$$F = k x_f = P_f A$$

$$\Rightarrow k x_f^2 = P_f A x_f$$

$$\boxed{k x_f^2 = P_f V_f}$$

$$h_i m_f = m_f u_f + P_f \frac{V_f}{2}$$

$$\Rightarrow h_i = u_f + \frac{P_f}{2}\left(\frac{V_f}{m_f}\right)$$

$$\Rightarrow \boxed{h_i = u_f + \frac{P_f v_f}{2}}$$

h_{supply}

Now u_f, P_f, V_f are correlated by eqn. of state, which is not known to us.

Hence we have to guess final T, after such few wise/logical guesses we find that

at $T = 362°C$

$h_f = 3163.94$ kJ/kg $\quad v_f = 0.14137$ m³/kg

$u_f = h_f - P_f v_f = 2881.2$ kJ/kg

hence $R.H.S = u_f + \frac{P_f v_f}{2} = 3022.57$ kJ/kg

$\approx$ LHS (3025 kJ/kg)

Hence $T_f \approx 362°C$