Tutorial - 3

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① At 110 kPa = 1.1 bar pressure,
from sat. liq. vapour table, T = 102.32°C

$v = v_g = 1.548 \ m^3/kg$
{at sat. vap}

The steam radiator's volume is fixed
⇒ v will remain const {as m is also fixed}

At $T = 25°C$ in saturated table,
$v_f = 0.00100\,29$ $\quad v_{fg} = 43.401$
$v_g = 43.40$

⇒ $v_f < v < v_g$ ⇒ final mix is sat. liq-vap mix.

$v = v_f + x v_{fg}$

$\therefore x = \dfrac{v - v_f}{v_{fg}} = \dfrac{1.548 - 0.0010029}{43.401} = 0.03564$

$\therefore x = 0.0356$

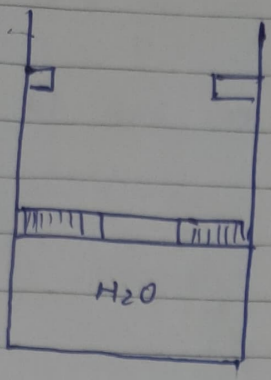
$\boxed{x \approx 0.036}$

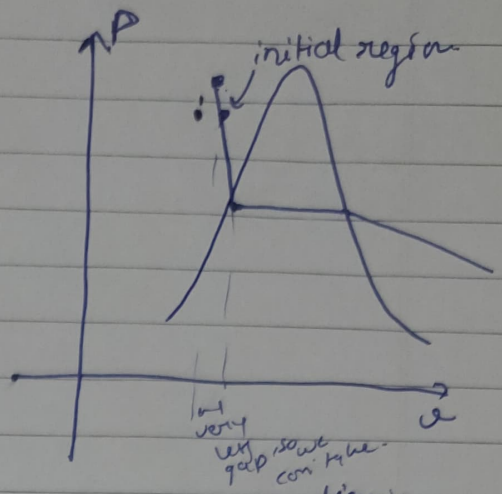
$P_{final} = P_{sat}$ at $T = 25°C = 0.03166$ bar

$\boxed{P = 3.166 \text{ kPa}}$

As Volume is const, $\therefore \boxed{\text{work done} = 0}$

(2)





As 3 bar unit available in compressed liquid table we should take $v = v_f$ at $T = 20^\circ C$ in saturated table.

$\therefore v = v_f = 0.0010017 \ m^3/kg.$

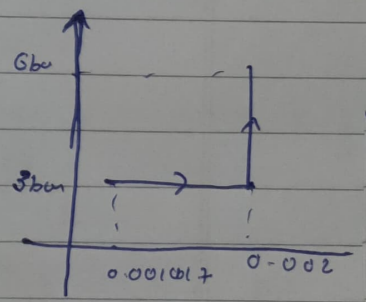
$V_{initial} = m \times v_g = 1 \times 0.0010017 \ m^3$

$= 0.0010017 \ m^3$

Initially the expansion would be at constant pressure (3bar) till it reaches the stops, then it would occur at const. volume

$\therefore W = \left(\int PdV\right)_1 + \left(\int PdV\right)_2$

$= P(V_2 - V_1) + 0$ (isochoric)



$= 3 \text{ bar} (0.002 - 0.0010017) \ m^3$

$= 3 \times 10^5 (0.0009983) = 299.49 \ J$

$\therefore W = 0.29949 \ kJ$

$\boxed{W \simeq 0.30 \ kJ}$

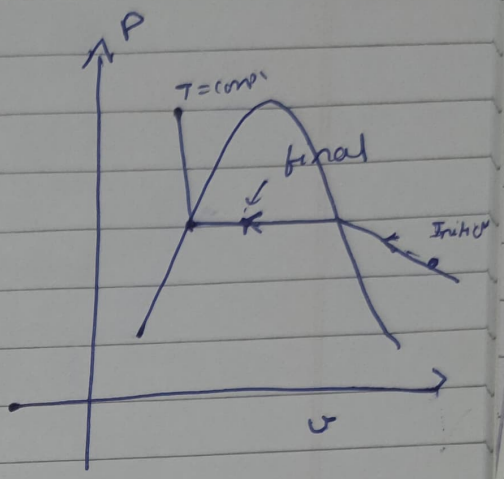
(8) $v_0 = \frac{3}{0.1} = 30\ m^3/kg$

At 40°C in saturated table, $v_f = 0.001007\ 8\ m^3/kg$

$v_g = 19.546\ m^3/kg$

$\because v_0 > v_g$

$\therefore$ Superheated vapour.



Given process is isothermal,

$T = 40°$,

Finally quality = 50%.

$\Rightarrow$ saturated region

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

$= (0.001007\ 8) + 0.5\ (19.545)$

$\boxed{v = 9.7735\ m^3/kg}$

Considering water-vapour to be an ideal gas undergoing isothermal process.

For Gas $w_1 = \int P dV = \int_{v_1}^{v_2} \frac{nRT}{V} dV = nRT \ln\left(\frac{v_2}{v_1}\right) = \frac{100}{18} \times 8.314 \times (313) \times \ln\left(\frac{v_2}{v_1}\right)$

$= 14.457 \ln\left(\frac{v_2}{v_1}\right)$ kJ

$v_2 = m v_g = \left(\frac{m_{tot}}{2}\right) \cdot v_g$; $v_1 = \frac{m_{tot}}{2} \cdot v_0$

Where $\frac{m_{tot}}{2}$ as that mass only still vapour

$\therefore W_1 = 14.457 \ln\left(\frac{v_g}{v_0}\right) = 14.457 \ln\left(\frac{19.546}{30}\right) = -6.1938$ kJ

PTO

For the other part, Conversion would be take place at constant pressure = P_{sat} = 0.07378 bar

= 7.375 kPa

$\therefore W_2 = 7.375 \times 10^3 \left(\underbrace{9.7735 - 19.546}_{\text{change in sp. vol}} \right) \underbrace{0.1}_{\text{mass}}$ kJ

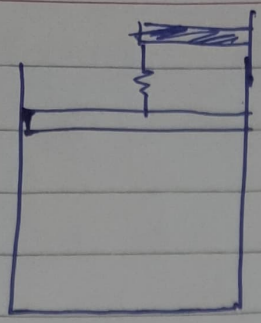
$= 7.375 \times (-9.7725) \times 0.1$ kJ

$= -7.20721$ kJ

$W = W_1 + W_2 = -6.1938 - 7.20721$

$$\boxed{W = -13.4010 \text{ kJ}}$$

(4) (a)



m remains const

$\Rightarrow v_{final} = \frac{V_{final}}{m} = 0.1\ m^3/kg$

$P_{final} = 3\ MPa = 30\ bar$

At 30 bar, $v_f = 0.001216\ m^3/kg$

$v_g = 0.066596\ m^3/kg$

$\because v > v_g \quad \therefore$ Superheated vapour.

$\therefore$ At 30 bar, $v = 0.1\ m^3/kg$, we find T.

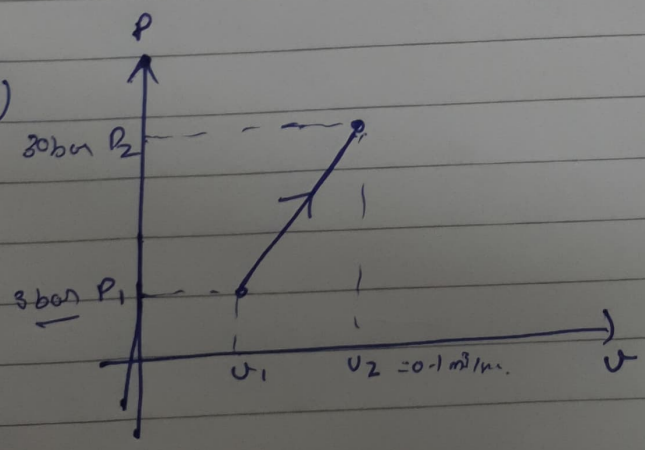
For 30 bar, 400°C $\rightarrow v = 0.09936\ m^3/kg$

450°C $\rightarrow v = 0.10787\ m^3/kg$

By interpolation. $\frac{450 - T}{450 - 400} = \frac{0.10787 - 0.1}{0.10787 - 0.09936}$

$\therefore \boxed{T = 403.760\ °C}$

(b)



(c) Initial $v =$

20°C, 3bar $\Rightarrow$ $P > P_{sat}$ $\Rightarrow$ Compressed Liq.

$\Rightarrow$ $v = v_f =$ 0.0010017 m^3/kg

{As no value found at 20°C.}

From figure we can see that

$$W = \frac{1}{2}(P_1 + P_2)(v_2 - v_1)\, m_{mass}$$

$$= \frac{1}{2}(30+3)\times 10^5 \times (0.1 - 0.0010017) \times 1 \text{ J}$$

$$\boxed{W = 163.347 \text{ KJ}}$$

(5) In a polytropic process, $PV^{n} = \text{const}$

$\{PV^{n} = \text{const}\}$

$\therefore P\left(\frac{T}{P}\right)^{n} = \text{const} \rightarrow P^{1-n} T^{n} = \text{const}$

$\Rightarrow \boxed{P T^{n/1-n} = \text{const.}}$

$P_1 T_1^{n/1-n} = P_2 T_2^{n/1-n}$

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

$\ln\left(\frac{P_2}{P_1}\right) = \frac{n}{1-n} \ln\left(\frac{T_1}{T_2}\right)$

$\frac{n}{1-n} = \frac{\ln(P_2/P_1)}{\ln(T_1/T_2)} \rightsquigarrow n = \frac{\ln(P_2/P_1)}{\ln(T_1/T_2) + \ln(P_2/P_1)}$

$n = 1.96873$

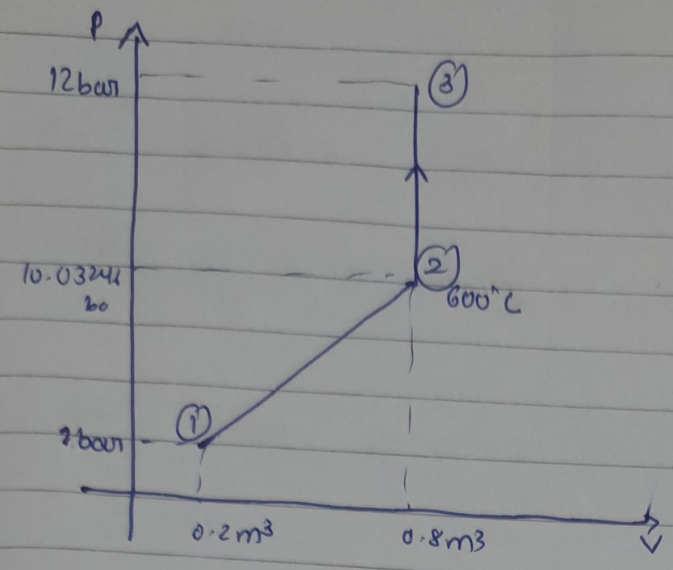
$\Rightarrow \boxed{n \approx 1.969}$

$W = \frac{P_1 V_1 - P_2 V_2}{n-1} = \frac{RT_1 - RT_2}{n-1}$

$= \frac{0.287(325 - 500)}{0.969}$

$= -51.846 \text{ kJ} \approx \boxed{W = -51.8 \text{ kJ}}$

⑥



At state ③

$m = 2kg$

$V = 0.8 m^3$

$v = \frac{0.8}{2} = 0.4 \ m^3/kg$

At 12 bar,

$v_g = 0.16421 \ m^3/kg$

$\therefore v > v_g$

⇒ superheated vap.

At 12 bar, in superheated table

At $T = 700°C \rightarrow v = 0.37294 \ m^3/kg$

$T = 800°C \rightarrow v = 0.4177 \ m^3/kg$

⇒ By interpolation, $\frac{T-700}{800-700} = \frac{0.4-0.37294}{0.4177-0.37294}$

$= 770.455 \ °C$

$\therefore \boxed{T = 770°C}$

$W = \int P dV = \frac{1}{2}(1+10.03246)(100)(0.6)$

$= 330 \ kJ$

$\left\{ P_2 = 10.03246 \ , \ \frac{P_1}{T_1} = \frac{P_2}{T_2} \right\}$

$\frac{P_1}{P_2} = \frac{(770+273)}{(600+273)} \Rightarrow P_2 = \frac{12 \times 873}{1043} = 10.03246 \ bar$

(7) 1kg, 20°C, $V = 0.1 m^3$

$P = 400 kPa = 4 bar$

$v = \frac{V}{m} = 0.1 m^3/kg$

At 4 bar in sat. table, $v_f = 0.001084 m^3/kg$

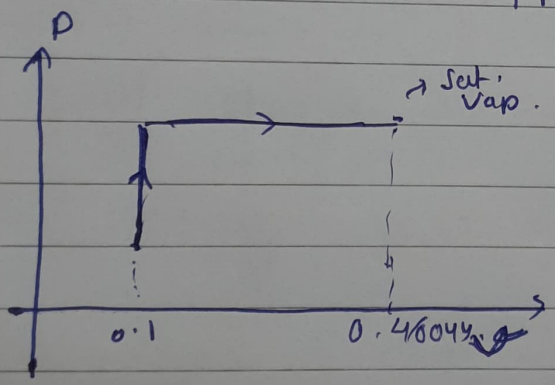
$v_g = 0.46044 m^3/kg$

$\because v_f < v < v_g$

$\Rightarrow$ Sat. liq-vap mix

$\Rightarrow T = T_{sat}$ at 4bar $= 143.63°C$

$\boxed{T \approx 143.6°C}$



$W = P(v_2 - v_1) m$

$= 4 \times 10^5 (0.46044 - 0.1) 1$

$= 144176 J$

$\boxed{W = 144.176 kJ}$

$V_{final} = m v_{final} = 1 \times 0.46044 m^3$

$\therefore \boxed{V = 0.46044 m^3}$

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(8) $m = 0.1\ kg$

$p = 1\ bar$

$x = 0.25$

$P_{gas} = 5\ bar$ for equilibrium of piston.

At 5 bar, $v_f = 0.001093\ m^3/kg$

$v_g = 0.3682\ m^3/kg$

Initially $v = v_f + x v_{fg}$

$v_f = 0.001044\ m^3/kg$

$v_g = 1.677\ m^3/kg$

$v_{fg} = 1.67596\ m^3/kg$

$= 0.001044 + 0.25 \times 1.67596$

$= 0.420034\ m^3/kg$

v won't change as m & V are const

$\therefore$ Finally $v > v_g \Rightarrow$ Superheated vap.

$P_{final} = 5\ bar$ as eq.

$T = 200°C \rightarrow 0.42492\ m^3/kg$

Now, $T = 300°C$, $v = 0.52256\ m^3/kg$ for 5 bar

$\Rightarrow V_f = m v = 0.052256\ m^3$

$W = p(v_2 - v_1) m$

$= 5 \times 10^5 (0.52256 - 0.42) \times 0.1\ J$

$W = 5.128\ kJ$

$W \approx 5.128\ kJ$