· MIN-106 - Tutorial 3

Shashank Aital
19114076 - Batch 04
Branch: CSE

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Q.1. At 25°C, by using steam table, we find that

Pressure = 3.166 kPa  $\Rightarrow \boxed{v = v_g = 1.548\ m^3/kg\ @\ 1.1\ bar}$

$v_f = 0.0010029\ m^3/kg$

$v_{fg} = 43.401\ m^3/kg$

$\Rightarrow 1.548 = 0.0010029 + x(43.401)$

$\Rightarrow \boxed{x = 0.0356}$    $\boxed{W = 0}$ ← ∵ Volume doesn't change

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Q.2. $m = 1kg$,

Initial sp. volume = $v_f$ @ 300 kPa = $0.001074\ m^3/kg$

→ Initial volume = $0.001074\ m^3$

→ Work = $P\Delta V$

⇒ Work = $300\,kPa\,(0.002 - 0.001074)\,m^3$

$= 0.3 kJ.$

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Q.3. Initial volume = $3m^3$, $m = 0.1kg$, $T = 40°C$, $x_{final} = 50\% = 0.5$

Initially, the system undergoes an isothermal process

$\Rightarrow W = \int P dV$    $PV = const = k$ (say)

$= k\ln(V_2/V_1)$

$\Rightarrow W = PV\ln\left(\frac{V_2}{V_1}\right) = PV\ln\left(\frac{P_1}{P_2}\right)$

$\Rightarrow W = nRT\ln\left(\frac{\frac{n_1 R T_1}{V_1}}{P_2}\right)$

Now, at $T = 40°C$, the saturation pressure = 0.07375 bar

= 7375 Pa

(from steam table)

$\Rightarrow P_2 = 7375 \text{ Pa}$

$$\Rightarrow W = \left(\frac{100}{18}\right) \times 8.314 \times 313 \times \ln\left(\frac{\frac{\left(\frac{100}{18}\right) \times 8.314 \times 313}{3}}{7375}\right)$$

$$= 14{,}457.122 \times \ln\left(\frac{14{,}457.122}{3 \times 7375}\right)$$

$$= -6{,}151.809 \text{ J}$$

$$= \underline{\underline{-6.151 \text{ kJ}}}$$

Once, it reaches saturation liquid-gas mixture, pressure remains constant.

At $T = 40°C$,

Now, initial specific volume = $v_g = 19.546 \text{ m}^3/\text{kg}$

Final specific volume = $v_f + x v_{fg}$

$$= 0.0010078 + 0.5 \times 19.545$$

$$= 9.7735 \text{ m}^3/\text{kg}$$

$$\Rightarrow W = P \Delta V$$

$$= 7.375 (9.7735 - 19.546) \times 0.1 \text{ kJ}$$

$$= \underline{\underline{-7.207 \text{ kJ}}}$$

Total work = $-6.151 - 7.207$

$$= \underline{\underline{-13.358 \text{ kJ}}}$$

$$\simeq \underline{\underline{-13.4 \text{ kJ}}}.$$

Q.4. $m = 1kg$; $T_i = 20°C$ & $P_i = 300kPa$ ; $P_f = 3000\ kPa$ ; $V_f = 0.1m^3$

(a) At $T = 20°C$, $v_f = 0.0010017\ m^3/kg$

$v_g = 57.84\ m^3/kg$

and $P = 0.02337\ bar < 300kPa$
$(= 2.337\ kPa)$

$\Rightarrow$ Compressed Liquid

Finally, @ 3 MPa, $v_f = 0.001216\ m^3/kg$
$v_g = 0.066596\ m^3/kg$

$\Rightarrow v = \frac{0.1}{1} = 0.1\ m^3/kg > v_g$

$\Rightarrow$ Superheated steam.

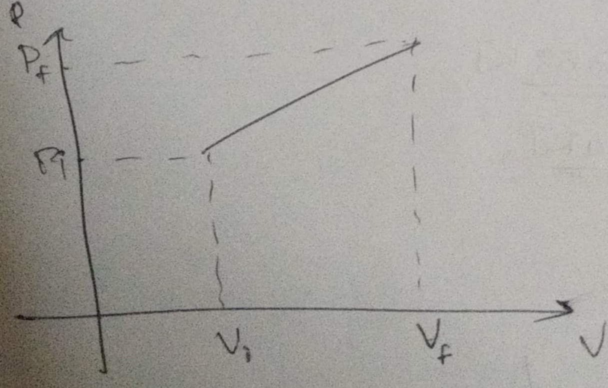
At 30 bar, $T = 400°C \Rightarrow v = 0.09936\ m^3/kg$
$T = 450°C \Rightarrow v = 0.10787\ m^3/kg$

$$\Rightarrow 0.1 = 0.09936 + \frac{0.10787 - 0.09936}{50}(T - 400)$$

$$\Rightarrow \frac{0.00064 \times 50}{0.00851} = T - 400$$

$$\Rightarrow \boxed{T = 403.76°C}$$

(b) $\because$ Piston attached to spring $\Rightarrow$



(c) Work = area under PV curve

$$= \frac{1}{2}(P_i + P_f)(V_f - V_i)$$

$$= \frac{1}{2}(300 + 3000)(0.1 - 0.0010017)$$

$$= \frac{1}{2} \times 3300 \times 0.0989983$$

$$= \underline{\underline{163.347 \text{ kJ}}}$$

$$V_i = \frac{V_f}{m} = \frac{0.0010017}{1} = 0.0010017 \ m^3/kg$$

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Q.5. $P_i = 125 \text{ kPa}$, $T_i = 325 \text{K}$ | $P_f = 300 \text{ kPa}$ ; $T_f = 500 \text{ k}$

Polytropic $\Rightarrow PV^n = \text{const.}$

$$\Rightarrow P^{n-1} \propto T^n$$

$$\Rightarrow \left(\frac{500}{325}\right)^n = \left(\frac{300}{125}\right)^{n-1}$$

$$\Rightarrow n \log\left(\frac{500}{325}\right) = (n-1)\log\left(\frac{300}{125}\right)$$

$$\Rightarrow n = \frac{\log\left(\frac{300}{125}\right)}{\log\left(\frac{300}{125} \times \frac{325}{500}\right)}$$

$$\Rightarrow \boxed{n = 1.9687}$$

Specific work:

$$P^{n-1} \propto T^n$$

$$\Rightarrow P^{n-1} = kT^n$$

$$\Rightarrow (n-1)\log P = n \log T + \log k$$

$$\Rightarrow (n-1)\frac{dP}{P} = n\frac{dT}{T} \rightarrow (1)$$

$$\frac{PV}{m} = RT$$

$$\Rightarrow \frac{PdV}{m} + \frac{VdP}{m} = RdT \rightarrow (2)$$

$$\text{Specific work} = \int \frac{PdV}{m}$$

$$= \int RdT - \frac{VdP}{m} \rightarrow \text{From (2)}$$

$$= \int \left( R\,dT - \frac{RT}{P}\,dP \right) \qquad \left(\because \frac{V}{m} = \frac{RT}{P}\right)$$

$$= \int \left( R\,dT - \frac{Rn}{n-1}\,dT \right) \qquad (\text{From } 1)$$

$$= -\frac{R}{n-1} \int dT)$$

$$= -\frac{0.287058 \times 175}{0.969}$$

$$= \underline{\underline{-51.842\,kJ}}$$

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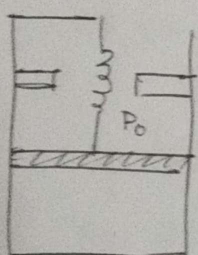
Q-6. $P_i = P_0 = 100\,kPa$, $V_i = 0.2\,m^3$ $m = 2kg$




Just hit : $V = 0.8\,m^3$, $T = 600°C$

Final : $V_f = 0.8\,m^3$, $P = 1.2\,MPa$

<u>Sol$^n$</u> (a) Final temp:

At $P = 1.2\,MPa$, $v_f = 0.001139\,m^3/kg$

$v_g = 0.162921\,m^3/kg$

$\Rightarrow v = \frac{0.8}{2} = 0.4 > v_g \Rightarrow$ Superheated steam

$\Rightarrow$ At $1.2\,MPa$,

$T = 700°C \Rightarrow v = 0.37294\,m^3/kg$

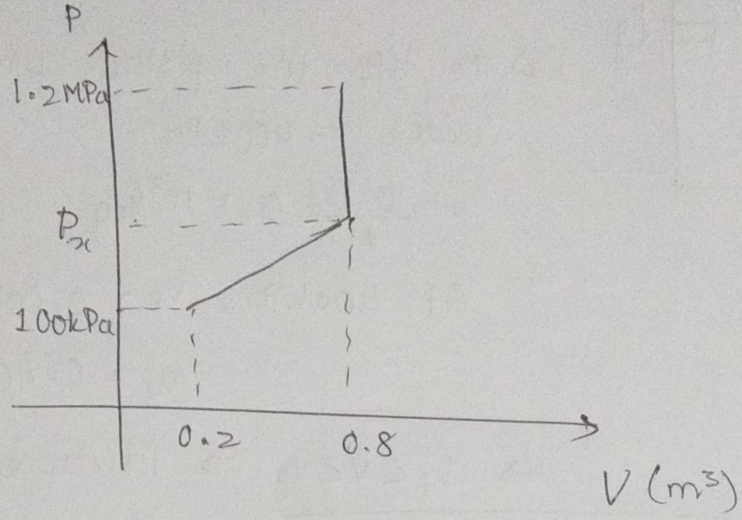
$T = 800°C \Rightarrow v = 0.41177\,m^3/kg$

$$\Rightarrow 0.4 = 0.37294 + \frac{0.41177 - 0.37294}{100}(T - 700)$$

$$\Rightarrow \frac{0.02706 \times 100}{0.03883} = T - 700$$

$$\Rightarrow \boxed{T = 769.688°C}$$

(b) P-V diagram-




(c) At $T = 600°C \Rightarrow$ superheated steam , $v = 0.4\ m^3/kg$

~~P= 100kPa ⇒ v= 4.02781 m³/kg~~

~~P = 200 kPa ⇒ V= 2.01297 m³/kg~~

$P = 1\ MPa \Rightarrow v = 0.40109\ m^3/kg$

$P = 1.2 MPa \Rightarrow v = 0.33393\ m^3/kg$

$$\Rightarrow 0.4 = 0.40109 - \left(\frac{0.40109 - 0.33393}{0.2}\right)(P_x - 1)$$

$$\Rightarrow P_x - 1 = \frac{0.00109 \times 0.2}{0.06716}$$

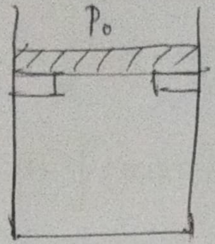
$$\Rightarrow P_x = \underline{1.00325\ MPa}$$

$$W = \frac{1}{2}(P_x + 100kPa)(0.8 - 0.2)$$

$$= 0.3 \times (1103.25)$$

$$= \underline{330.975\ kJ}$$

Q.7.




$m = 1 kg \quad T = 20°C, \quad V = 0.1 m^3$

(a) To lift the piston, pressure of water = 400 kPa

$v = \frac{0.1 \times 1}{1} = 0.1 \ m^3/kg$

At 400 kPa, $v_f = 0.001084 \ m^3/kg$

$v_g = 0.460444 \ m^3/kg$

$\Rightarrow v_f < v < v_g \Rightarrow$ Mixture

$\Rightarrow \boxed{T = T_{sat} = 143.63°C}$

(b) Heated to saturated vapor (Pressure remains constant)

(i) Final temperature $= T_{sat} = \underline{143.63°C}$

(ii) Final volume $= \frac{v_g}{m} = \frac{0.460444}{1} = \underline{0.460444 \ m^3}$

(iii) ${}_1W_2 = P(V_2 - V_1)$

$= 400(0.460444 - 0.1)$

$= \underline{144.1776 \ kJ}$

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Q8. $m = 0.1 kg, \quad P = 100 kPa, \quad x = 25\%; \quad P_{max} = 500 kPa, \quad T_f = 300°C$

(a) Final pressure: At 300°C, $P_{sat} = 8592.7 kPa$

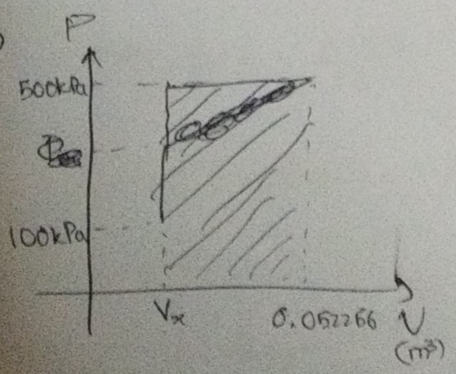
$\Rightarrow \boxed{\text{Final pressure} = P_{max} = 500 kPa}$

(b) Volume: State - superheated steam

$\Rightarrow v = 0.52256 \ m^3/kg \quad \Rightarrow V = 0.52256 \times 0.1$

$\boxed{V = 0.052256 \ m^3}$

(c)




At 100 kPa, $v_f = 0.001043 \ m^3/kg$

$v_g = 1.677 \ m^3/kg$

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

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

$= 0.001043 + 0.25 \times 1.67596$

$= 0.420033$

$\Rightarrow V_x = 0.0420033 \ m^3$

$\Rightarrow {}_1W_2 = P(V_2 - V_1) = 500(0.052256 - 0.0420033)$

$= 500(0.0102527)$

$= \underline{5.126 kJ}$

We get this value by using the steam table provided by Subodh Sir. If we use $v_{fg} = 1.6941$ we get expected ans. = [illegible]