MIN-106 - Tutorial 4

Shashank Aital
19114076 - Batch C4
Branch - CSE

Q.1. By 1st law,

$$\Delta Q = \Delta U + W$$

$$\Rightarrow 80 + 18.5 = 5(2659.5 - 2709.9) + W$$

$$\Rightarrow W = 98.5 + 251.5$$

$$\Rightarrow \boxed{W = 350 \text{ kJ}}$$

Q.2. $\Delta U = -55 \times \frac{1}{4} = -13.75 \text{ kJ}$

$$W = \int P dV = \int \frac{k dV}{V^{1.2}}$$

$$= \frac{k V^{-0.2}}{-0.2}$$

$$= \frac{PV}{-0.2}$$

$PV^{1.2} = k$

$(8)(0.02)^{1.2} = (2)(V_f)^{1.2}$

$\Rightarrow (V_f) = 4^{\frac{1}{1.2}} \times (0.02)$

$= 3.1748 \times 0.02$

$= 0.0635$

$$= \frac{1}{0.2}(800 \times 0.02 - 200 \times 0.0635)$$

$$= \frac{1}{0.2}(16 - 12.699)$$

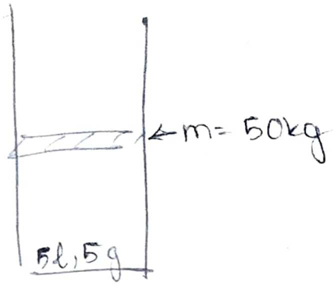
$$= \frac{1}{0.2}(3.301) = 16.5 \text{ kJ}$$

$$\Rightarrow Q = \Delta U + W$$

$$= 16.5 - 13.75$$

$$= \underline{2.75 \text{ kJ}}$$

Q.3.



$Q = \Delta U + W$

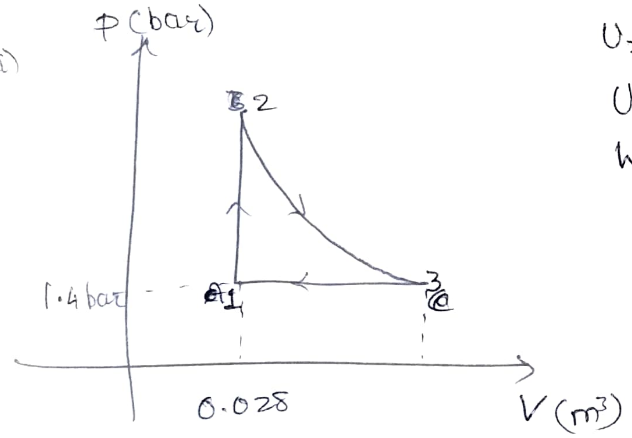
$= -\frac{260\times5}{1000} + \left(-100\times0.003 - \frac{\cancel{50}\times\cancel{10}\times0.3}{1000}\right)$

$= -1.3 - 0.3 - 4.9\times0.03$

$= -1.6 - 0.147$

$= \underline{-1.747\ kJ}$

Q.4. (a)



$U_2 - U_1 = 26.4\,kJ$

$U_3 = U_2$

$W_{31} = -10.5\,kJ$

(b) $W_{cycle} = W_{12} + W_{23} + W_{31}$

$= 0 + W_{23} - 10.5$

$= PV\ln\left(\frac{V_3}{V_2}\right) - 10.5$

$= 1.4\times10^2 \times \overset{0.103}{\cancel{0.028}} \times \ln\left(\frac{0.103}{0.028}\right) - 10.5$

$= \cancel{5.106 - 10.5}$

$= 18.782 - 10.5$

$= \underline{8.282\ kJ}$

$1.4(0.028 - V_2) \times 10^{\cancel{5}\,2} = -10.5$

$\Rightarrow V_2 - 0.028 = \frac{10.5}{1.4}\times10^{-2}$

$= 0.075$

$\Rightarrow V_2 = \underline{0.103\ m^3}$

(c) $Q = \Delta U + W$

$= 0 + PV\ln\left(\frac{V_3}{V_2}\right)$

$= \underline{18.782\,kJ}$

(d) $Q = \Delta U + W$

Also, $\Delta U_{cycle} = 0$

$\Rightarrow U_{12} + U_{23} + U_{31} = 0$

$\Rightarrow U_{31} = -(26.4 + 0)$

$= -26.4 \text{ kJ}$

$W_{31} = -10.5 \text{ kJ}$ (given)

$\Rightarrow Q_{31} = -(26.4 + 10.5)$

$= \underline{-36.9 \text{ kJ}}$

$\because W_{cycle} > 0$ & $Q_{cycle} = 26.4 + 18.782 - 36.9$

$\Rightarrow Q_{cycle} > 0$

$\Rightarrow$ $\boxed{\text{Cycle is a power cycle.}}$

Q.5 Initially, $m = 0.2 \text{ kg}$, $P = 400 \text{ kPa}$

That is $v = v_g = 0.460444 \text{ m}^3/\text{kg}$

Finally volume divides to half

$\Rightarrow v_{final} = 0.230222 \text{ m}^3/\text{kg}$

$\Rightarrow$ At 400 kPa, $v_f = 0.001084$, $v_{fg} = 0.459360$

$\Rightarrow 0.23022 = 0.001084 + x(0.459360)$

$\Rightarrow x = \dfrac{0.229136}{0.459360} = \underline{0.4988}$

Initial sp. enthalpy $= 2737.7 \text{ kJ/kg}$

Final $\Rightarrow h_f + x h_{fg}$

$= 605 + (0.4988)(2132.7)$

$=$ ~~1758.575 kJ/kg~~ $\underline{1668.79 \text{ kJ/kg}}$

$\Delta h = \cancel{1758.57}\ 1668.79 - 2737.7$

$= \cancel{-979.125\ kJ/kg}$ $\quad = -1068.91\ kJ/kg$

$\Rightarrow \cancel{Q = \Delta H = \Delta h \times m}$

$\cancel{= -979.125 \times 0.2}$

$=$

$Q = \Delta H = \Delta h \times m$

$= -1068.91 \times 0.2$

$= \underline{\underline{-213.78\ kJ}}$

Q.6 $\quad x = 0.7$

At $\quad P = 200\ kPa$,

$h_f = 504.7\ kJ/kg$ $\qquad h_{fg} = 2201.7\ kJ/kg$

$u_f = 504.49\ kJ/kg$ $\qquad u_{fg} = 2024.92\ kJ/kg$

$v_f = 0.001061\ m^3/kg$ $\qquad v_{fg} = 0.883908\ kJ/kg$

$\Rightarrow h_{ini} = h_f + x h_{fg} = 504.7 + 0.7 \times 2201.7$

$= 2045.89\ kJ/kg$

$u_{ini} = u_f + x u_{fg} = 504.49 + 0.7 \times 2024.92$

$= 1921.934\ kJ/kg$

$v_{ini} = v_f + x v_{fg} = 0.001061 + 0.7 \times 0.883908$

$= 0.6197966\ m^3/kg$

$\Rightarrow m = \dfrac{V}{v_{ini}} = \dfrac{0.1}{0.6197966} = \underline{\underline{0.1613\ kg}}$

At $200°C$ & $200\ kPa$ $\Rightarrow$ superheated steam

$\Rightarrow h = 2870.46\ kJ/kg$

$u = 2654.39\ kJ/kg$

$\Rightarrow \Delta h = h - h_{ini}$

$= 824.57$ kJ/kg

$\Delta u = u - u_{ini}$

$= 732.456$ kJ/kg

$\Rightarrow Q = \Delta H = m\Delta h = 0.1613 \times 824.57$

$= \underline{133 \text{ kJ}}$

$\Delta U = m\Delta u = 0.1613 \times 732.456$

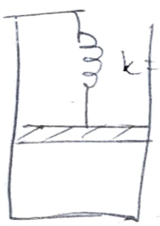
$= 118.145$ kJ

$Q = \Delta U + W$

$\Rightarrow W = 133 - 118.145$

$= \underline{14.85 \text{ kJ}}$

Q.7.



Initially, $P = P_{sat}$ @ 120°C $= \underline{1.9854 \text{ bar}}$.

$P = kx/A$

$\Rightarrow 198.54 = 15 \times x/0.05$

$\Rightarrow x_1 = \frac{198.54 \times 0.05}{15} = \underline{0.6618 \text{ m}}$

Finally $P = 500$ kPa

$\Rightarrow 500 = \frac{kx}{A}$

$\Rightarrow x_2 = \frac{500 \times 0.05}{15} = \frac{5}{3}$

~~$\Rightarrow V = Ax = \frac{0.25}{3}$~~

~~$\Rightarrow v = \frac{V}{m} = \frac{0.25}{3 \times 0.5} = \frac{1}{6}$~~

$\Rightarrow$ At 120°C, $v_g = 0.8915\ m^3/kg$

$\Rightarrow V = 0.8915 \times \frac{1}{2} = 0.44575\ m^3$

$\Rightarrow$ Initial length $= x_0 + x_1 = \dfrac{0.44575}{0.05}$

$= 8.915\ m$

$\Rightarrow x_0 = 8.915 - 0.6618$

$= \underline{\underline{8.2532 m}}$

$\Rightarrow$ Final volume $= A(x_0 + x_2)$

$= 0.05(8.2532 + 1.6667)$

$= 0.495995$

$\Rightarrow v = \dfrac{0.495995}{0.5} = 0.992\ m^3/kg$

Now $v > v_g$ @ 5 bar ($v_g = 0.36812$) $\Rightarrow$ Superheated steam.

At 5 bar,

At $T = 800°C$, $v = 0.98959\ m^3/kg$

At $T = 900°C$, $v = 1.08217\ m^3/kg$

$\Rightarrow 0.992 = 0.98959 + \dfrac{1.08217 - 0.98959}{100}(T - 800)$

$\Rightarrow T - 800 = \dfrac{0.241}{0.09258} = 2.6$

$\Rightarrow \boxed{T = 802.6°C}$

Initially, $h_{ini} = 2706 \text{ kJ/kg}$

Finally, At $T = 800°C$, $h = 4156.96 \text{ kJ/kg}$

At $T = 900°C$, $h = 4394.71 \text{ kJ/kg}$

$$h_{fin} = 4156.96 + \frac{4394.71 - 4156.96}{100}(3)$$

$$= 4164.0925 \text{ kJ/kg}$$

$\Rightarrow \Delta h = 1458.0925 \text{ kJ/kg}$

$\Rightarrow Q = \Delta H = m\Delta h$

$=$

Initially, $u_{ini} = 2529 \text{ kJ/kg}$

Finally, At $800°C$, $u = 3662.17 \text{ kJ/kg}$

At $900°C$, $u = 3853.63 \text{ kJ/kg}$

$$\Rightarrow u_{fin} = 3662.17 + \frac{3853.63 - 3662.17}{100}(3)$$

$$u_{fin} = 3667.9138 \text{ kJ/kg}$$

$\Rightarrow \Delta u = 1138.91 \text{ kJ/kg}$

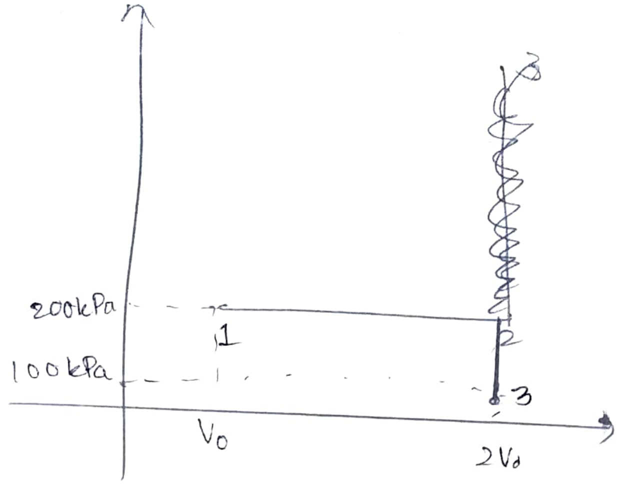
$Q = \Delta U + W$

$= m\Delta u + W = m\Delta u + \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$

$= 0.5 \times 1138.91 + \frac{1}{2}(500 + 198.54)(0.49599 - 0.44575)$

$= \underline{\underline{587 \text{ kJ}}}$

Q.8.



For state 2,

$\boxed{P_2 = 200\,kPa}$

$\because PV = nRT \Rightarrow V \propto T$

$\because$ V doubles, $\Rightarrow$ T doubles $\Rightarrow \boxed{T_2 = 1200K}$

Now C_p @ 1200K = $\cancel{1.005}$ 1.065 kJ/kgK

$\Rightarrow h_2 = C_p T = 1200 \times \cancel{1.005}$ 1.065 $\Rightarrow \boxed{h_2 = 1278\ kJ/kg}$

for state 3,

$PV = nRT \Rightarrow P \propto T$

$\therefore$ T halves $\Rightarrow$ P halves

$\Rightarrow \boxed{P_3 = 100\,kPa}$

$\boxed{T_3 = 600k}$ - - - given

Now C_p @ 600k = 1.0125 kJ/kgk

$\Rightarrow h_3 = C_p T_3 = 600 \times 1.0125$

$\Rightarrow \boxed{h_3 = 607.5\ kJ/kg}$

$\boxed{W_{23} = 0}$ $(\because \Delta V = 0)$

$Q_{23} = C_V \Delta T$

$= (0.83)(-600)$

$= -498 \text{ kJ/kg}$

Q.9. $P_1 V_1 = P_2 V_2$

$\Rightarrow (150)(0.001)^{1.25} = (600)(V_2)^{1.25}$

$\Rightarrow V_2 = \left(\frac{1}{4}\right)^{\frac{1}{1.25}}(0.001)$

$= 0.00032988 \ m^3$

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

$= \frac{(600)(0.00032988) - (150)(0.001)}{1-1.25}$

$= \frac{-0.047928}{0.25} = -0.1917 \text{ kJ}$

$\Delta U = m C_V \Delta T$

& $PV = mRT$

$\Rightarrow m = \frac{150 \times 0.001}{0.287 \times 300} = 0.001742 \text{ kg}$

Also, $T_2 = \frac{P_2 V_2}{mR} = \frac{600 \times 0.00032988}{0.001742 \times 0.287} = 395.58$

$\Rightarrow \Delta U = 0.001742 \times 0.718 \times (395.58 - 300)$

$\Rightarrow \boxed{\Delta U = 0.11993 \text{ kJ}}$

$\boxed{Q = \Delta U + W = -0.072 \text{ kJ}}$

Q. 10. $P_1 = 400\,kPa$, $T_1 = 600\,k$

$P_2 = 150\,kPa$, $T_2 = 400\,k$

$PV^n = \text{constant}$

$\Rightarrow P\left(\frac{T}{P}\right)^n = \text{constant}$

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

$\Rightarrow \left(\frac{\cancel{400}^{8}}{\cancel{150}_{3}}\right)^{n-1} = \left(\frac{3}{2}\right)^n$

$\Rightarrow (n-1)\log\left(\frac{8}{3}\right) = n\log\left(\frac{3}{2}\right)$

$\Rightarrow \log\left(\frac{8}{3}\right) = n\left[\log\left(\frac{8}{3}\times\frac{2}{3}\right)\right]$

$\Rightarrow n = \frac{\log(8/3)}{\log(16/9)} = \underline{\underline{1.70471}}$

$\Rightarrow PV^{1.70471} = \text{const.}$

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

$\Rightarrow \frac{W}{m} = \frac{P_2V_2 - P_1V_1}{1-n} \times \frac{1}{m}$

$= \frac{R(T_2 - T_1)}{1-n}$

$= \frac{(0.287)(-200)}{-0.70471}$

$= \frac{200 \times 0.287}{0.70471} = \underline{\underline{81.45\ kJ/kg}}$

$\frac{Q}{m} = q = \cancel{Q}\, W + \Delta U$

$\Rightarrow q = 81.45 + C_v\Delta T = 81.45 - 0.717(200)$

$= \underline{\underline{-61.95\ kJ/kg}}.$