Tutorial 4, Ayushman Tripathy, MIN-106
{Q-1 to 5}

(1) Given:

$u_1 = 2709.9$ kJ/kg $\Rightarrow U_1 = 2709.9 \times 5$ kJ
$u_2 = 2659.6$ kJ/kg $\Rightarrow U_2 = 2659.6 \times 5$ kJ

$Q_{in} = Q = 80$ kJ

$\underset{\{by\ sys\}}{W} = W_{piston} + (-W_{by\ paddle})$

$= W_p - 18.5$ kJ

We have, by first law of thermodynamics:

$Q = \Delta U + W$

$\Rightarrow 80 = (2659.6 - 2709.9) \times 5 + W_p - 18.5$

$= -251.5 + W_p - 18.5$

$= -270 + W_p$

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

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(2) Given: $\Delta U = -55\ kJ/kg \times 0.25\ kg$

$= -13.75\ kJ$

Given process is polytropic, with $m = 1.2$

$\{ p V^{1.2} = const \}$

$P_1 = 8$ bar, $P_2 = 2$ bar

$V_1 = 0.02\ m^3$, $V_2 = V$

$\Rightarrow 8 \times (0.02)^{1.2} = 2 \times V^{1.2}$

$\Rightarrow V = 0.02 \times 4^{1/1.2} = 0.02 \times 2^{5/3} = 0.063496 m^3$

We know that W in a poly-tropic process $pv^m = const$

i.e. $W = \dfrac{P_1V_1 - P_2V_2}{m-1}$

$$\Rightarrow W = \left(\frac{8 \times 10^5 \times 0.02 - 2 \times 10^5 \times 0.063496}{0.2} \right) \times 10^{-3} kJ$$

$= 16.5039\ kJ$

By first law, $Q = \Delta U + W$

$= -13.75 + 16.5039$

$= 2.7539\ kJ$

$\therefore \boxed{Q = 2.7539\ kJ}$

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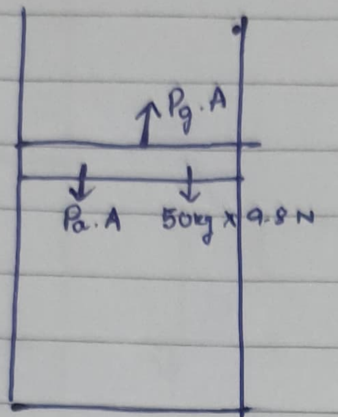
(3)



As the process is slow, equilibrium will always be maintained,
thus heat transfer would occur at a constant pressure.

$$\Delta U = (\Delta u) \cdot m = -260 \text{ kJ/kg} \times (5 \times 10^{-3} \text{ kg})$$

$$= -1.3 \text{ kJ}$$

By equilibrium of piston :-

$$P_g \cdot A = P_a \cdot A + mg$$

$$\Rightarrow P_g = P_a + \frac{mg}{A} = 100 \text{ kPa} + \frac{50 \times 9.8}{0.01} \times 10^{-3}$$

$$= 149 \text{ kPa}$$

$$W = \int_{V_1}^{V_2} P dV = P \int_{V_1}^{V_2} dV = P(V_2 - V_1) = 149 \text{ kPa} (2 \times 10^{-3} - 5 \times 10^{-3}) \text{ m}^3$$

$$= -0.447 \text{ kJ}$$

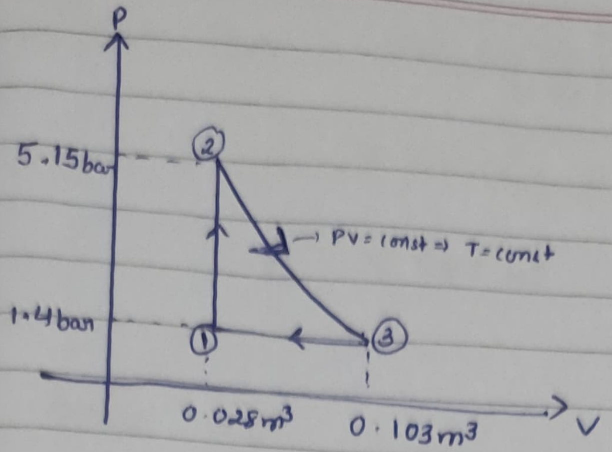
$$Q = \Delta U + W$$

$$= -1.3 - 0.447$$

$$\boxed{Q = -1.747 \text{ kJ}}$$

(4)

(a)



Process 1, $\Delta V = 0 \Rightarrow Q_1 = \Delta U_1 = 26.4\ kJ$

$W_1 = 0$

Process 2, $T = const \Rightarrow \Delta U = 0$

$\Rightarrow Q_2 = W_2$

Process 3, $P = const \Rightarrow W = P(V_1 - V_3)$

$= 1.4 \times 10^2 (0.028 - V_3)$

$= -10.5\ kJ$

$\Rightarrow V_3 = 0.103 m^3$

$\because P_2 V_2 = P_3 V_3$ {Process 2 ⇒ PV = const}

$\Rightarrow P_2 = \frac{1.4 \times 0.103}{0.028} = 5.15\ bar$

(b) $W_{net} = W_1 + W_2 + W_3 = 0 + PV \ln\left(\frac{V_3}{V_2}\right) + W_3$

$= 5.15 \times 10^2 \times 0.028 \ln\left(\frac{0.103}{0.028}\right) + (-10.5)$

$\approx 18.782 - 10.5$

$\approx 8.2824\ kJ \Rightarrow \boxed{W_{net} = 8.282 kJ}$

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(c) $Q_{23} = W_{23} = PV \ln\left(\frac{V_3}{V_2}\right)$

$= 5.15 \times 10^2 \times 0.028 \ln\left(\frac{0.103}{0.028}\right)$

$= 18.782 \text{ kJ}$

(d) $\Delta U_{net} = 0$

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

$= -0 - 26.4 \text{ kJ}$

$\Delta U_{31} = -26.4 \text{ kJ}$

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

$Q_{31} = \Delta U_{31} + W_{31} = -26.4 - 10.5 = -36.9 \text{ kJ}$

$\therefore \boxed{Q_{31} = -36.9 \text{ kJ}}$

(3) Given constant pressure process with $P = 4\,bar$

Initially saturated vapour $\Rightarrow v = v_g = 0.460444\ m^3/kg$

Finally, $V' = \frac{V}{2} \Rightarrow v' = \frac{v}{2} = 0.230222\ m^3/kg$

$\because P = 4\ bar$

In saturated table at 4bar, $v_f = 0.001084\ m^3/kg$

$v_g = 0.460444\ m^3/kg$

$\because v_f < v < v_g \Rightarrow$ mix. of sat. liq. & vap.

$$x = \frac{v - v_f}{v_{fg}} = \frac{0.230222 - 0.001084}{0.459360}$$

$$= 0.49882$$

$h_{final} = h_f + x\,h_{fg}$

$= 605.0 + 0.49882 \times 2132.7$

$= 1668.8336\ kJ/kg$

$h_{initial} = h_g$

$= 2737.7\ kJ/kg$

$\Delta h = (1668.8336 - 2737.7)$

$= -1068.8663\ kJ/kg$

$\Delta H = m\,\Delta h$

$= 0.2 \times -1068.8603 = -213.77\ kJ$