MIN 106 - Tutorial 7

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Q.1. Control Volume: Water in cylinder

(I) 3MPa, $x_1 = 0.5$ $\Rightarrow T_1 = 233.9°C$

$v_1 = v_f + x_1 v_{fg}$

$= 0.001216 + 0.5 \times 0.06546$

$= 0.033948 \ m^3/kg$

$u_1 = u_f + x_1 u_{fg} = 1004.75 + 0.5 \times 1597.86$

$= 1803.68 \ kJ/kg$

$s_1 = s_f + x s_{fg} = 2.6458 + \cancel{0.5 \times 3.60}$ 0.5×3.5378

$= 4.4147 \ kJ/kgK$

$m_1 = \frac{V_1}{v_1} = \frac{0.02}{0.033948} = \underline{0.589 \ kg}$

Now, $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

${}_1Q_2 = 600kJ$, ${}_1W_2 = 124 kJ$

Now, $u_2 = 1803.68 + \frac{600 - 124}{0.589} = \underline{2611.8294 \ kJ/kg}$

(II) $P_2 = 1.2MPa$, $u_2 = 2611.8294 \ kJ/kg$

$T_2 \approx 200°C$ (From superheated table)

$s_2 = 6.5898 \ kJ/kgK$

$$\Delta s = m(s_2 - s_1) - \frac{Q_{cv}}{T_H} \quad , \; T_H = 300°C, \; Q_{cv} = {}_1Q_2$$

$$= 0.589(6.5898 - 4.4147) - \frac{600}{300 + 273.15}$$

$$= 1.28 - 1.0468$$

$$= 0.2332 \text{ kJ/k} \geq 0$$

$\Rightarrow$ The process is possible.

Q.2. Say, final temperature is T.

$$5\, C_{steel}(250 - T) = 5\, C_{steel}(T - 25)$$

$$\Rightarrow T = \frac{275}{2} = \underline{\underline{137.5°C}}$$

$$\Delta s = m\, C_{steel} \ln \frac{T_2}{T_1} \Rightarrow S_{gen} = 5\, C_{avg}\left[\ln \frac{T}{T_1} + \ln \frac{T}{T_2}\right]$$

$$= 5 \times 0.46 \times \ln\left[\frac{(273.15 + 137.5)^2}{(273.15 + 250)(273.15 + 25)}\right]$$

$$= \underline{\underline{0.1794 \text{ kJ/k}}}$$

Q.3. Control Volume: Air in tank

$$m(u_2 - u_1) = {}_1Q_2 - {}_1W_2 \quad ; \quad {}_1W_2 = -100\text{kJ}$$

Now, $m(s_2 - s_1) = \int \frac{dQ}{T} + {}_1S_2{}_{gen}$

$$= \frac{{}_1Q_2}{T_{amb}} + {}_1S_2{}_{gen}$$

<u>Process</u>: Rigid $\Rightarrow V_1 = V_2$

(I) $\Rightarrow$ $T_1 = 20°C$, $P_1 = 200\text{kPa}$, $m_1 = 2\text{kg}$

(II) $\Rightarrow$ $T_2 = 80°C$, $V_1 = V_2$ ($\because$ Container is rigid)

Ideal gas $\Rightarrow$ $\left.\begin{array}{l} R = 0.287 \text{ kJ/kgk} \\ C_v = 0.717 \text{ kJ/kgk} \end{array}\right\}$ given

$$_1Q_2 = mC_v(T_2 - T_1) + {}_1W_2$$

$$= 2\times 0.717(80-20) - 100$$

$$= -14 \text{ kJ}$$

Also, $$s_2 - s_1 = C_v \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{V_2}{V_1}\right)$$

$$= C_v \ln\left(\frac{T_2}{T_1}\right) \quad (\because V_2 = V_1)$$

$$\Rightarrow s_2 - s_1 = 0.717 \ln\left(\frac{273.15+80}{273.15+20}\right)$$

$$= 0.13756 \text{ kJ/kgK}$$

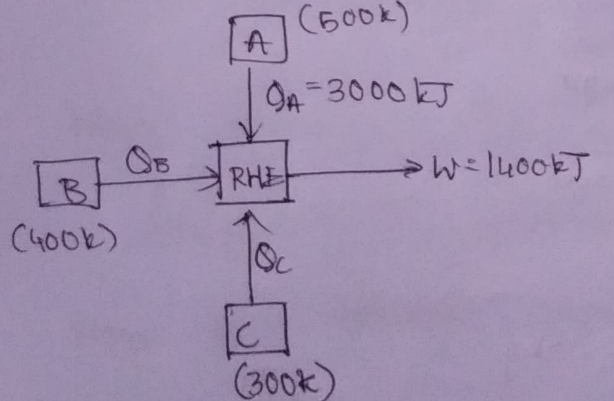
$$_1S_{2\,gen} = m(s_2 - s_1) - \frac{_1Q_2}{T_{amb}}$$

$$= 2\times 0.13756 + \frac{14}{293.15}$$

$$= 0.3229 \text{ kJ/K} > 0$$

$\Rightarrow$ $\boxed{\text{Process is possible}}$

Q.4.



Now, $Q_A + Q_B + Q_C = W$

$$\Rightarrow \boxed{Q_B + Q_C = -1600 \text{ kJ}}$$

∵ Heat Engine is Reversible

$$\Rightarrow \Delta s = 0$$

$$\Rightarrow \frac{Q_A}{T_A} + \frac{Q_B}{T_B} + \frac{Q_C}{T_B} = 0$$

$$\Rightarrow \frac{\overset{600}{3000}}{500} + \frac{Q_B}{400} + \frac{Q_C}{300} = 0$$

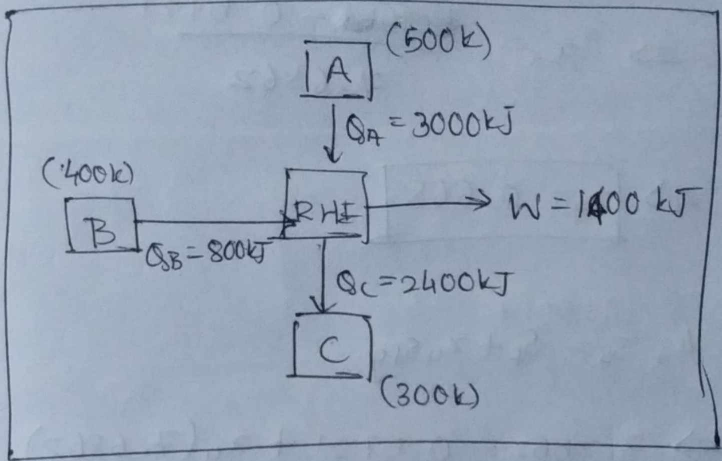
$$\Rightarrow 3Q_B + 4Q_C = -7200$$

$\Rightarrow 3(-1600 - Q_c) + 4Q_c = -7200$

$\Rightarrow \boxed{Q_c = -2400 \text{ kJ}}$

$\Rightarrow Q_B = 2400 - 1600 = \underline{800 \text{ kJ}}$

Final heat transfers with directions:



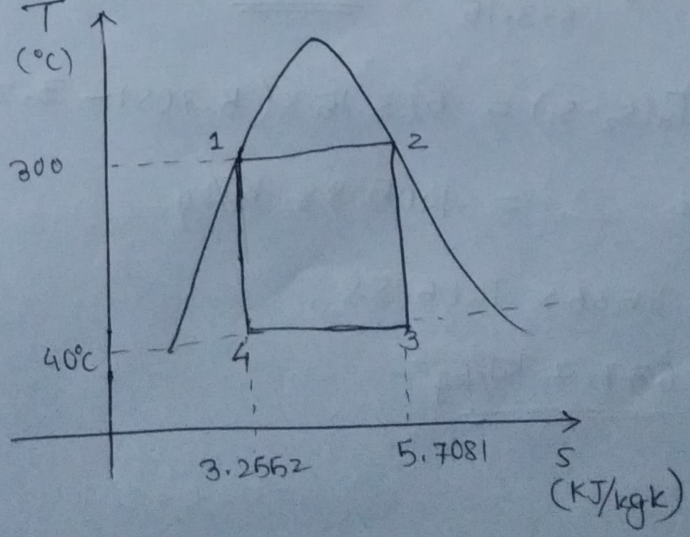
Q.5. Carnot cycle $\Rightarrow$ 2 Isothermal & 2 Isoentropic processes.

Now, At state 1 $\Rightarrow$ saturated liquid

$\Rightarrow S_1 = S_4 = S_f @ 300°C = 3.2552$ kJ/kgK

Also, state 2 $\Rightarrow$ saturated vapor

$\Rightarrow S_2 = S_3 = S_g @ 300°C = 5.7081$ kJ/kgK



Now @ 40°C, $S_f = 0.5721$ kJ/kgK

$S_{fg} = 7.6862$ kJ/kgK

$\Rightarrow$ For state 3, $S_3 = S_f + x_3 S_{fg}$

$\Rightarrow 5.7081 = 0.5721 + x_3(7.6862)$

$\Rightarrow x_3 = \dfrac{5.7081 - 0.5721}{7.6862}$

$\Rightarrow \boxed{x_3 = 0.668}$

$\Rightarrow$ For state 4, $S_4 = S_f + x_4 S_{fg}$

$\Rightarrow 3.2552 = 0.5721 + x_4(7.6862)$

$\Rightarrow x_4 = \dfrac{3.2552 - 0.5721}{7.6862}$

$\Rightarrow \boxed{x_4 = 0.349}$

$W = q \times \eta$ and $\eta = \dfrac{W}{q} \Rightarrow \eta = \dfrac{T_H - T_L}{T_H}$

$\Rightarrow \eta = \dfrac{260}{573.15} = \underline{0.4536}$.

$q = T_H(S_2 - S_1) = 573.15 \times (5.7081 - 3.2552)$

$= 1405.88$ kJ/kg

$W = 0.4536 \times 1405.88$

$= \underline{637.7 \text{ kJ/kg}}$

Q. 6. (I) ⇒ Saturated water vapor @ 200kPa

$$\Rightarrow v_1 = v_g = 0.884969 \ m^3/kg$$

$$h_1 = 2706.4 \ kJ/kg$$

$$s_1 = 7.1267 \ kJ/kgK$$

(II) ⇒ $P_2 = P_1 = 200kPa$, $v_2 = \frac{v_1}{2} = 0.442484 \ m^3/kg$

$$v_f = 0.001061 \ m^3/kg$$

$$v_{fg} = 0.883908 \ m^3/kg$$

$$\Rightarrow x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{0.442484 - 0.001061}{0.883908}$$

$$= \underline{0.5}$$

$$\Rightarrow h_2 = h_f + x_2 h_{fg}$$

$$= \cancel{2201.7}\ 504.7 + 0.5 \times 2201.7$$

$$\Rightarrow h_2 = \underline{1605.55 \ kJ/kg}$$

$$s_2 = s_f + x_2 s_{fg}$$

$$= 1.5304 + 0.5 \times 5.5963$$

$$= \underline{4.32855 \ kJ/kgk}$$

$$_1W_2 = P(V_2 - V_1) = mP(v_2 - v_1)$$

$$= 0.75 \times 200 (0.442484 - 0.884969)$$

$$= \underline{-66.37275 \ kJ}$$

$$_1Q_2 = m(h_2 - h_1)$$

$$= 0.75(1605.55 - 2706.4)$$

$$= \underline{-825.6375 \ kJ}$$

$${}_1S_{2\,gen} = m(s_2 - s_1) - \frac{{}_1Q_2}{T}$$

$$= 0.75(4.32855 - 7.1267) + \frac{825.6375}{293.15}$$

$$= -2.09861 + 2.816433$$

$$= \underline{0.717 \text{ kJ/k}}$$

Q.7.

(I) $\Rightarrow$ $P = 150$ kPa, $T = 20°C$ $\Rightarrow$ Compressed Liquid

$$\left.\begin{aligned} \Rightarrow v_1 &= 0.0010017 \text{ m}^3/\text{kg} \\ u_1 &= 83.86 \text{ kJ/kg} \\ s_1 &= 0.2963 \text{ kJ/kgk} \end{aligned}\right\} \text{Values for saturated liquid @ 20°C.}$$

(II) $\Rightarrow$ $P = 1$ MPa, $T = 500°C$ $\Rightarrow$ Superheated vapor

$v_2 = 0.35411$ m^3/kg

$u_2 = 3124.34$ kJ/kg

$s_2 = 7.7621$ kJ/kgk

Now, $P = A + BV$ ...given (A & B are constants)

$$\Rightarrow {}_1W_2 = \frac{1}{2}(P_1 + P_2)(v_2 - v_1)$$

$$\Rightarrow {}_1W_2 = \frac{1}{2}(1000 + 150)(0.35411 - 0.0010017)(1)$$

$$= \underline{203.037 \text{ kJ}}$$

$${}_1Q_2 = m(u_2 - u_1) + {}_1W_2$$

$$= 1(3124.34 - 83.86) + 203.037$$

$$= \underline{3243.517 \text{ kJ}}$$

$${}_1S_{2gen} = m(s_2 - s_1) - \frac{{}_1Q_2}{T}$$

$$= 1(7.7621 - 0.2963) - \frac{3243.517}{273.15 + 600} \quad (\because T_{source} = 600°C)$$

$$= 7.4658 - 3.7147$$

$$= \underline{\underline{3.7511 \text{ kJ/k}}}$$

Q.8. Control Volume: Nitrogen Gas

(I) $\Rightarrow T = 200°C,\ P = 300kPa$

(II) $\Rightarrow \boxed{P_2 = P_{eq} = 200kPa}$

$$m = \frac{P_1V_1}{RT_1} = \frac{300 \times 0.005}{0.2968 \times 473.15}$$

$$= \underline{\underline{0.01068 \text{ kg}}}$$

Now, $m_1u_1 + P_1V_1 = m_2u_2 + P_2V_2 = mh_2$

$$\Rightarrow C_pT_2 = C_vT_1 + \left(\frac{P_2}{P_1}\right)RT_1 \qquad \left(\text{Put } m = \frac{P_1V_1}{RT_1}\right)$$

$$\Rightarrow T_2 = \frac{C_v}{C_p}T_1 + \left(\frac{P_2}{P_1}\right)\left(\frac{R}{C_p}\right)T_1$$

$$\Rightarrow T_2 = \frac{\left[0.745 + \left(\frac{200}{300}\right) \times 0.2368\right]}{1.042} \times 473.15$$

$$\Rightarrow \boxed{T_2 = 428.13 K}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\Rightarrow V_2 = 0.005 \times \frac{300}{200} \times \frac{428.15}{473.15} \Rightarrow \boxed{V_2 = 0.00679 m^3}$$

$${}_1S_{2gen} = m(s_2 - s_1) - \frac{{}_1Q_2}{T} \qquad (\text{Given } {}_1Q_2 = 0)$$

$$\Rightarrow {}_1S_{2gen} = m(s_2 - s_1)$$

Assuming Ideal gas,

$${}_1S_{2gen} = mC_p \ln\left(\frac{T_2}{T_1}\right) - mR \ln\left(\frac{P_2}{P_1}\right)$$

$$\Rightarrow {}_1S_{2gen} = 0.01068\left[1.042 \ln\left(\frac{428.13}{473.15}\right) - 0.2968 \ln\left(\frac{200}{300}\right)\right]$$

$$\Rightarrow \boxed{{}_1S_{2gen} = 0.000173 \text{ kJ/K}}$$
