MIN-106

Tutorial 7

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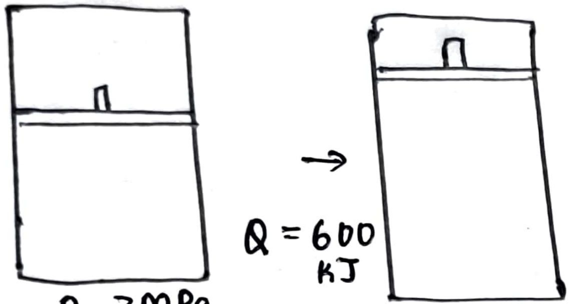
1)



$Q = 600$ kJ

$P = 3$ MPa
$x = 50\%$
$V = 20$ L

$P = 1.2$ MPa
$T = 300°C$
$W_d = 124$ kJ

@ 3MPa, $x = 0.5 \Rightarrow T = 233.9$ °C

$$v_1 = v_f + x v_{fg}$$

$$= 0.001216 + 0.5(0.06546)$$

$$= 0.033948 \text{ m}^3/\text{kg}$$

$$u_1 = x_1 u_{fg_1} + u_{f_1} = 1004.75 + 0.5(1597.86)$$

$$= 1803.68 \text{ kJ/kg}$$

$$s_1 = s_f + x s_{fg} = 2.6458 + 0.5(3.5378)$$

$$= 4.4147 \text{ kJ/kgK}$$

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

$m(u_2 - u_1) = Q_{1\to2} - W_{1\to2}$

$Q_{1\to2} = 600 kJ$
$W_{1\to2} = 124 kJ$

$u_2 = 1803.68 + \frac{600 - 124}{0.589}$

$= 2611.8294 \frac{kJ}{kg}$

(II) $P_2 = 1.2 MPa$, $u_2 = 2611.8294 \frac{kJ}{kg}$

$T_2 = 200°C$

$S_2 = 6.5898 \frac{kJ}{kgK}$

$\Delta S = m(S_2 - S_1) - \frac{Q_{cv}}{T_4}$ $\Rightarrow T_4 = 300°C$
$Q_{cv} = Q_2$

$= 0.589(6.5898 - 4.4147) - \frac{600}{573.15}$

$= 1.28 - 1.0468$

$= 0.2332 \frac{kJ}{K} \geq 0$

$\Rightarrow$ The process is possible

2)

5kg
T= 523K

5kg
T= 298K

$$ms(523-T) = ms(T-298)$$

$$523+298 = 2T$$

$$\boxed{410.5\,K = T}$$

$$= 137.5^\circ C$$

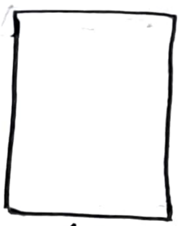
$$\Delta S = m\,C_{steel} \ln\left(\frac{T_2}{T_1}\right) \qquad C_{steel} = C_{avg} = 0.46$$

$$= 5(0.46)\left[\ln\left(\frac{T_f}{T_1}\right) + \ln\left(\frac{T_f}{T_2}\right)\right]$$

$$= 5(0.46)\left[\ln\left(\frac{410.5}{523}\right) + \ln\left(\frac{410.5}{298}\right)\right]$$

$$= 0.1794\ kJ/K$$

3)



$\Delta V = 0$

$$m(U_2-U_1) = Q_{1\to2} - W_{1\to2}\ , \qquad W_{1\to2} = -100\,kJ$$

$$m(S_2-S_1) = \int \frac{dQ}{T} + S_{1\to2\,gen}$$

$$= \frac{Q_{1\to2}}{T} + S_{1\to2\,gen}$$

$\therefore V_1 = V_2$

(I) $T_1 = 20^\circ C$, $P_1 = 200\,kPa$ $\quad m_1 = 2kg$

(II) $T_2 = 80^\circ C$, $V_1 = V_2$ (container is rigid)

Ideal gas → $R = 0.287\ \frac{kJ}{kgK}$

$C_v = 0.717\ \frac{kJ}{kgK}$

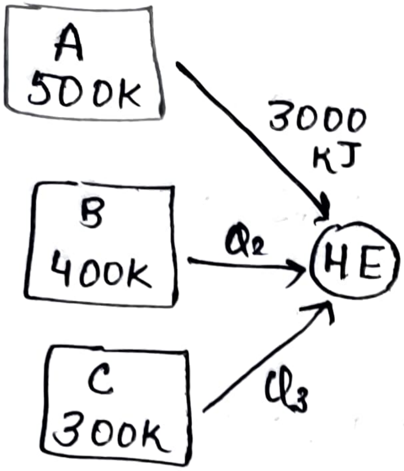
$$Q_{1\to2} = mC_v(T_2 - T_1) + W_{1\to2}$$
$$= 2\times0.717(80-20) - 100$$
$$= -14\,kJ$$

$$S_2 - S_1 = C_v \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{V_2}{V_1}\right)$$
$$= C_v \ln\left(\frac{T_2}{T_1}\right)$$
$$= 0.717 \ln\left(\frac{353.15}{293.15}\right)$$
$$= 0.13756\ \frac{kJ}{kgK}$$

$$S_{1\to2gen} = m(S_2 - S_1) - \frac{Q_{1\to2}}{T_{ambient}}$$
$$= 2(0.13756) + \frac{14}{293.15}$$
$$= 0.3229\ \frac{kJ}{kgK} \geq 0$$

$\boxed{\text{POSSIBLE}}$

4)



$$\frac{3000}{500} + \frac{Q_2}{400} + \frac{Q_3}{300} = 0$$

(B/C $\Delta S = 0$, REV)

ALSO: $3000 + Q_2 + Q_3 = 1400$
(REV)

$$\Rightarrow Q_2 + Q_3 = -1600 \text{ KJ}$$

$$6 + \frac{Q_2}{400} + \frac{Q_3}{300} = 0$$

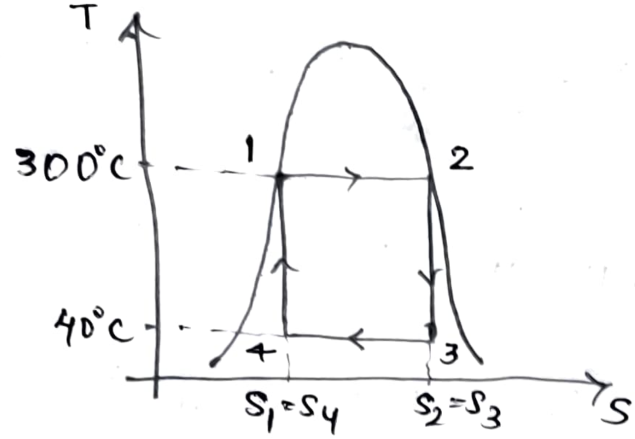
$$6 + \frac{(-1600 - Q_3)}{400} + \frac{Q_3}{300} = 0$$

$$7200 - 4800 - 3Q_3 + 4Q_3 = 0$$

$$\boxed{\begin{array}{l} Q_3 = -2400 \text{ KJ} \\ \Rightarrow Q_2 = 800 \text{ KJ} \end{array}}$$

Q_3: 2400 KJ from engine to source
Q_2: 800 KJ from source to engine

5)



State 1 in saturated liquid state @ 300°C

@ 300°C: $s_f = 3.2533 \frac{kJ}{kg K}$

$s_1 = 3.2533$ kJ/kg K

$\boxed{s_1 = s_4} \Rightarrow s_4 = 3.2533$ kJ/kg K

@ 40°C: $s_f = 0.5724$ kJ/kg K

$s_{fg} = 7.6845$ kJ/kg K

$s_4 = s_f + x s_{fg}$

$3.2533 = 0.5724 + x(7.6845)$

$\Rightarrow x = \frac{3.2533 - 0.5724}{7.6845}$

$\boxed{x_4 = 0.3489}$

Similarly, state 2 is sat. vapour state @ 300°C

@ 300°C: $s_g = 5.7044$ kJ/kg K

$s_2 = 5.7044$ kJ/kg K

$\boxed{s_2 = s_3} \Rightarrow s_3 = 5.7044$ kJ/kg K

s_3 is at 40°C

$s_3 = s_{f\,40°C} + x\, s_{fg\,40°C}$

$= 0.5724 + x(7.6845)$

$$S_3 = 5.7044 = 0.5724 + x_3(7.6845)$$

$$\Rightarrow \boxed{x_3 = 0.6678}$$

Since it is a carnot engine:

$$\eta = \frac{W}{Q_H} = 1 - \frac{T_L}{T_H}$$

$$= 1 - \frac{40+273}{300+273} = \frac{260}{573}$$

$$\boxed{\eta = 0.4536}$$

work output $= \eta \times Q_H$

$$Q_H = T_H(S_2 - S_1)$$

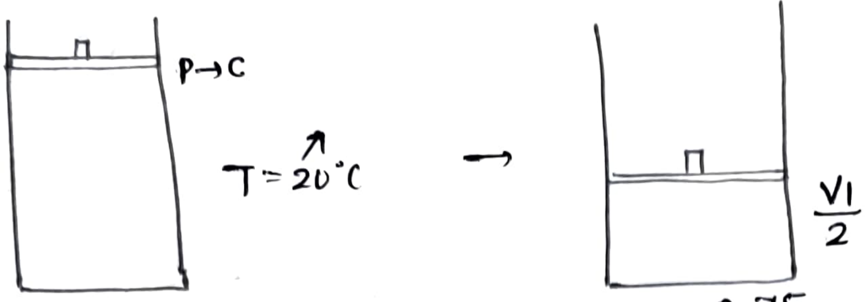
$$= 573(5.7044 - 3.2533) = 1404.48$$

$$Q_H \approx 1405.0 \text{ kJ/kg}$$

$$W = (0.4536)(1405)$$

$$\boxed{\therefore \text{work output} = 637.308 \ \frac{kJ}{kg}}$$

6]



0.75 kg sat. vapour

200 kPa

= 2 Bar

m = 0.75

$\frac{V_1}{2}$

200 kPa

(1) @ 2 Bar: $T = 120.23°C$

$v_g = 0.884969\ \frac{m^3}{kg}$

$h_g = 2706.4\ \frac{kJ}{kg}$

$m = 0.75\,kg \Rightarrow V_1 = (0.75)(0.884969)$

$= 0.66372675\ m^3$

$h_1 = m h_g$

$= (0.75)(2706.4)\ \frac{kJ}{kg} = 2029.8\ kJ$

(2) @ 2 Bar, $V_2 = \frac{V_1}{2} = \frac{0.66372675}{2} = 0.331863375\ m^3$

$m = 0.75$

$\Rightarrow v_2 = \frac{V_2}{m} = \frac{0.331863375}{0.75} = 0.4424845$

$v_2 = v_f + x\,v_g$ @ 2 Bar, 120.23°C

$0.4424845 = 0.001061 + x(0.883908)$

$\Rightarrow x = 0.4993998$

$W = P(V_2 - V_1)$

$= -(200)(0.331863375)\ kJ$

$= -66.372 \simeq -66.22\ kJ$

$$Q = W + \Delta U$$

$$\Delta U = m(u_2 - u_1)$$

$$u_1 = 2529.41 \frac{kJ}{kg}$$

$$u_2 = u_f + x\, u_{fg}$$

$$= 504.49 + (0.4993998)(2024.92)$$

$$= 1515.73464 \frac{kJ}{kg}$$

$$\Delta U = (0.75)(1515.73464 - 2529.41)$$

$$\boxed{\Delta U = -760.2565 \text{ kJ}}$$

$$Q = W + \Delta U$$

$$= -66.372 - 760.2565$$

$$\boxed{Q = -826.6285 \text{ kJ}}$$

$$S_{gen} = \Delta S_{system} + \Delta S_{surrounding}$$

$$= m(s_2 - s_1) + \frac{826.6285}{20 + 273.15} \rightarrow \left(\frac{Q}{T_{surr}}\right)$$

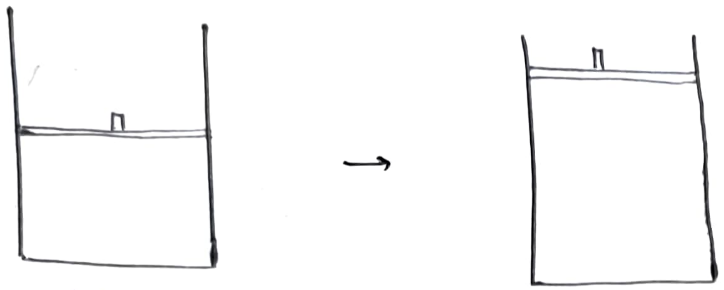
$$= \cancel{0.75(x s_{fg})} + \frac{826.6285}{293.15}$$

$$0.75(x-1)(s_{fg})$$

$$= 0.75(0.4993998 - 1)(5.5963) + \frac{826.6285}{293.15}$$

$$\boxed{S_{gen} = 0.71868 \frac{kJ}{K}}$$

7)



1 kg
(1.5 Bar) 150 kPa
20°C

1 kg
1000 kPa (10 Bar)
500°C

$v_f = 0.0010017 \frac{m^3}{kg}$

COMP. LIQUID

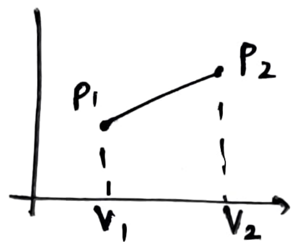
$v_g = 0.35411 \frac{m^3}{kg}$

~~SAT~~. SUPERHEATED VAPOUR

$Q = W + \Delta U$

$W = \int P dV$

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



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

$V_1 = m v_f$
$= 1(0.0010017)$

$V_2 = m v_g$
$= 1(0.35411)$

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

$\boxed{W = 203.037 \text{ kJ}}$

$\Delta U = m(U_2 - U_1)$

$U_1 = u_{f\, 20°C,\, 150 kPa} = (83.86)(1) \text{ kJ}$; $U_2 = U_{g\, 500°C,\, 10 Bar} = \left(3124.34 \frac{kJ}{kg}\right) 1 kg$

$\Rightarrow \Delta U = 3124.34 - 83.86 = \boxed{3040.48 \text{ kJ}}$

$\Rightarrow Q = (203.037 + 3040.48) \text{ kJ} =$

$Q = \boxed{3243.5 \text{ kJ} \simeq 3243.4 \text{ kJ}}$

$$\Delta S_{total} = \Delta S_{sys} + \Delta S_{surr}$$

• $\Delta S_{sys} = m(S_2 - S_1)$

$$= \cancel{m}\ 1\left(S_{g\,500^\circ C,\ 10\,Bar} - S_{f\,20^\circ C,\ 150\,kPa}\right)$$

$$= (7.7621 - 0.2963)$$

$$= 7.4658\ kJ/K$$

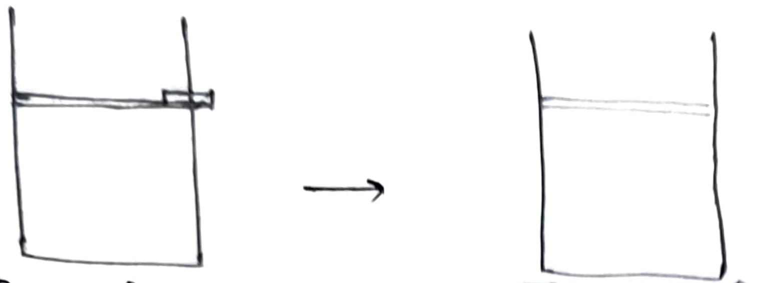
• $\Delta S_{surr} = \dfrac{-Q_{sys}}{T_{surr}} = \dfrac{-3243.4}{873.15}$

$$= -3.7145\ \frac{kJ}{K}$$

$$\Delta S_{total} = 7.4658 - 3.7145\ \frac{kJ}{K}$$

$$\Delta S_{total} = \boxed{3.751\ \frac{kJ}{K}}$$

8)



T_1 200°C
P_1 300 kPa
V_1 5L

$P_2 = 200$ kPa
V_2
T_2

$Q = 0$

$$m = \frac{P_1 V_1}{RT_1} = \frac{(300)(5)\times 10^{-3}}{0.2968 \times 473.15} = 0.01068 \text{ kg}$$

$$(200)(V_2) = m(0.2968)(T_2)$$

$$m_1 u_1 + P_1 V_1 = m_2 u_2 + P_2 V_2 = m h_2$$

$$C_p T_2 = C_v T_1 + \left(\frac{P_2}{P_1}\right)(RT_1)$$

$$T_2 = \frac{C_v}{C_p} T_1 + \frac{P_2 R T_1}{C_p P_1}$$

$$T_2 = \frac{0.745}{1.042}(473.15) + \frac{200}{300} \times \frac{0.2368}{1.042} \times 473.15$$

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

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\Rightarrow V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(300)(5)(428.13)}{(473)(200)}$$

$$\boxed{V_2 = 0.00679 \text{ m}^3}$$

$$\Delta S_{total} = \Delta S_{system} + \Delta S_{surrounding}$$

$\Delta S_{surr} = 0$ b/c NO HEAT TRANSFER

$$\Delta S_{system} = m(S_2 - S_1)$$

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

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

$$\boxed{\Delta S = 0.000173 \ \frac{kJ}{K}}$$