MIN-106-Tutorial 8

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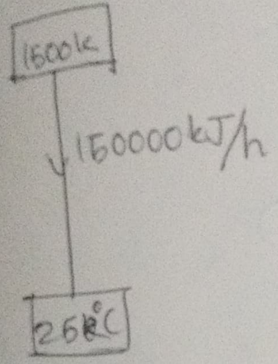
Q.1.



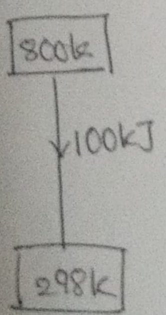
$$\dot{X} = \left(1 - \frac{T_0}{T}\right)\left(\frac{150000}{3600}\right)$$

$$= \left(1 - \frac{298}{1500}\right)\left(\frac{1500}{36}\right)$$

$$= \frac{1500 - 298}{36}$$

$$= \underline{\underline{33.38\,kW}}$$

Q.2.

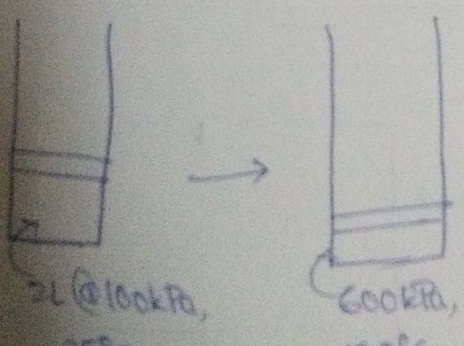


$$X = \left(1 - \frac{298}{800}\right)(100)$$

$$= \frac{502}{800} \times 100$$

$$= \underline{\underline{62.75\,kJ}}$$

Q.3.



$W_{useful} = 1.2\,kJ$

Surroundings: 100kPa, 25°C

(a) $\boxed{X_1 = 0}$ (Dead state)

$$m_1 = \frac{P_1 V_1}{R T_1} = \frac{100 \times 0.002}{0.287 \times 298} = \underline{\underline{0.00234\,kg}}$$

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} = \underline{\underline{0.473L}}$$

$$S_2 - S_0 = C_p \ln T_2/T_0 - R\ln P_2/P_0$$

$$= 1.009 \ln \frac{423}{298} - 0.287 \ln \frac{600}{100}$$

$$= -0.1608 \ kJ/kgK$$

$$X_2 = m\left[C_v(T_2 - T_0) - T_0(S_2 - S_0)\right] + P_0(V_2 - V_1)$$

$$(\because X_2 = (U_2 - U_0) + P_0(V_2 - V_0) - T_0(S_2 - S_0))$$

$$\Rightarrow X_2 = 0.00234\left[0.732(423-298) - 298(-0.1608)\right] + 100(0.000473 - 0.002)$$

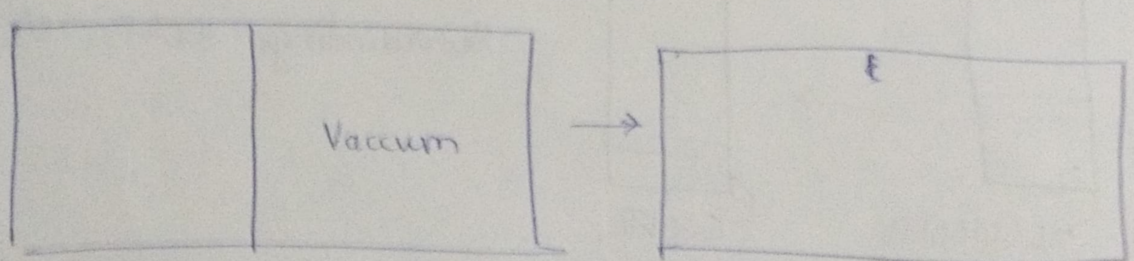
$$= \underline{\underline{0.171\,kJ}}$$

(b) $(X_{in} - X_{out}) - X_{destroyed} = \Delta X_{system}$

$$W_{rev} = X_2 - X_1 = 0.171 - 0 = \underline{\underline{0.171\,kJ}}$$

(c) $$\eta_{II} = \frac{W_{rev}}{W_u} = \frac{0.171}{1.2} = 0.143 = \underline{\underline{14.3\%}}$$

Q.4



1.6kg, 300kPa, 60°C

1.5kg, 15kPa

Surr: 25°C, 100kPa

Initially, compressed liquid @ 300 kPa, 60°C

$\Rightarrow v_1 = 0.001017 \ m^3/kg$

$u_1 = 251.236 \ kJ/kg$

$s_1 = 0.83114 \ kJ/kgK$

Finally, volume doubles $\Rightarrow v_2 = 0.002034 \ m^3/kg$

At 15 kPa, $v_f = 0.001014 \ m^3/kg$

$v_{fg} = 9.994 \ m^3/kg$

$\Rightarrow$ Saturated liquid-vapor mixture

$$\Rightarrow x = \frac{v_2 - v_f}{v_{fg}} = \frac{0.002034 - 0.001014}{9.994}$$

$$= \underline{\underline{0.0001}}.$$

$u_2 = u_f + x u_{fg}$

$= 226.08 + 0.0001 \times 2223.38$

$= \underline{\underline{226.3023 \ kJ/kg}}$

$s_2 = s_f + x s_{fg}$

$= 0.7553 + 0.0001 \times 7.2537$

$= \underline{\underline{0.75602 \ kJ/kgK}}$

Now, $X_{des} = X_{initial} - X_{final}$

$= [(U_1 - U_0) - T_0(S_1 - S_0) + P_0(V_1 - V_0)]$

$- [(U_2 - U_0) - T_0(S_2 - S_0) + P_0(V_2 - V_0)]$

$= [U_1 - U_2] - T_0(S_1 - S_2) + P_0(V_1 - V_2)$

$= (1.5)(251.236 - 226.3023) - 298 \times 1.5(0.83114$

$- 0.75602) + 100(-0.001017)$

$= 37.40119 - 33.57864 + 0.15255 = \underline{\underline{3.67 \ kJ}}$

Q.5.

8 MPa, 450°C $\xrightarrow{h = \text{constant}}$ 6 MPa

$v_1 = 0.03817 \ m^3/kg$ $\qquad$ $v_2 = ?$

$h_1 = 3271.99 \ kJ/kg$ $\qquad$ $h_2 = 3271.99 \ kJ/kg$

$s_1 = 6.555 \ kJ/kgK$ $\qquad$ $s_2 = ?$

At 6 MPa, $\quad T = 400°C$ $\qquad\qquad$ $T = 450°C$

$V_{400} = 0.04739 \ m^3/kg$ $\qquad$ $V_{450} = 0.05214 \ m^3/kg$

$h_{400} = 3177.17 \ kJ/kg$ $\qquad$ $h_{450} = 3301.76 \ kJ/kg$

$S_{400} = 6.5407 \ kJ/kgK$ $\qquad$ $S_{450} = 6.7192 \ kJ/kgK$

Using interpolation,

$$\frac{V_2 - V_{400}}{V_{450} - V_{400}} = \frac{S_2 - S_{400}}{S_{450} - S_{400}} = \frac{h_2 - h_{400}}{h_{450} - h_{400}}$$

$$\Rightarrow \frac{V_2 - 0.04739}{0.05214 - 0.04739} = \frac{S_2 - 6.5407}{6.7192 - 6.5407} = \frac{3271.99 - 3177.17}{3301.76 - 3177.17}$$

$$\Rightarrow V_2 = 0.04739 + 0.00476 \times \frac{94.82}{124.59}$$

$$= \underline{0.051 \ m^3/kg}$$

$$\Rightarrow S_2 = 6.5407 + 0.1785 \times \frac{94.82}{124.59}$$

$$= \underline{\underline{6.676538 \ kJ/kgK}}$$

$\Rightarrow \Delta X = X_1 - X_2$

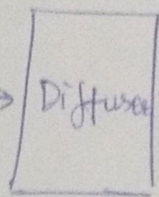
$= (h_1 - h_2) - T_0(s_1 - s_2)$

$= -T_0(s_1 - s_2)$

$= 298.15(6.676538 - 6.555)$

$= \underline{\underline{36.2365 \text{ kJ/kg}}}$

Q.6.

10kPa, 50°C, 300m/s →  → 50°C, 70m/s, $A = 3m^2$

$h_1 = \cancel{2684.7}$ 2592.56 kJ/kg
$v_1 = \cancel{14.659}$ 14.86920 m^3/kg
$s_1 = \cancel{8.1507}$ 8.1749 kJ/kgK

$h_2 = 2592.2$ kJ/kg
$v_2 = 12.046$ m^3/kg
$s_2 = 8.0776$ kJ/kgK

Volume flow rate, $\dot{V}_2 = A v_2$

$= 3 \times 70 = 210 \ m^3/s$

$\Rightarrow$ (a) $\dot{m}_2 = \dfrac{\dot{V}_2}{v_2} = \dfrac{210}{12.046} = \underline{\underline{17.433 \text{ kg/s}}}$

(b) $\Delta\psi = (h_2 - h_1) - T_0(s_2 - s_1) + \left(\dfrac{V_2^2}{2} - \dfrac{V_1^2}{2}\right)$

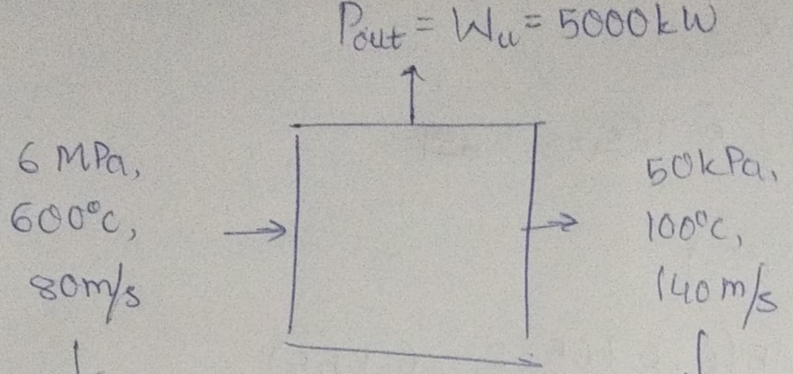
$= -0.36 + (298.15)(0.0973) + \frac{1}{2}(-85.1)$

$= -13.9$ kJ/kg

$\Rightarrow$ Wasted work $= 242.32$ kJ/sec

$= \underline{\underline{242.32 \text{kW}}}$

Q.7.



$v_1 = 0.06526\ m^3/kg$ $\qquad$ $v_2 = 3.41833\ m^3/kg$

$h_1 = 3658.4\ kJ/kg$ $\qquad$ $h_2 = 2682.52\ kJ/kg$

$s_1 = 7.1676\ kJ/kgK$ $\qquad$ $s_2 = 7.6947\ kJ/kgK$

∵ Turbine is adiabatic,

$$\dot{m}\left(h_1 + \frac{V_{e_1}^2}{2}\right) = \dot{W}_u + \dot{m}\left(h_2 + \frac{V_{e_2}^2}{2}\right)$$

$$\Rightarrow \dot{m}\left[3658.4 - 2682.52 + \frac{1}{2}(6.4 - 19.6)\right] = 5000$$

$$\Rightarrow \dot{m}[969.28] = 5000$$

$$\Rightarrow \underline{\dot{m} = 5.1585\ kg/s}$$

$$W_{rev} = -\Delta\psi \cdot \dot{m}$$

$$= \dot{m}\left[(h_1 - h_2) - T_0(s_1 - s_2) + \left(\frac{V_{e_1}^2}{2} - \frac{V_{e_2}^2}{2}\right)\right]$$

$$= \dot{m}\left(\left[3658.4 - 2682.52 + \frac{1}{2}(6.4 - 19.6)\right] - (298.15)\left[7.1676 - 7.6947\right]\right)$$

$$= \dot{m}\left[969.28 + 298.15(7.6947 - 7.1676)\right]$$

$$= 5.1585 \times 1126.434865 = \underline{5.84\ MW}$$

$$\eta_{II} = \frac{\dot{W}_u}{\dot{W}_{rev}} \quad \text{(For turbine)}$$

$$= \frac{5}{5.84}$$

$$= 0.856$$

$$\boxed{\eta_{II} = 85.6\%}$$ ← 2^{nd} law efficiency