1. (a) $\frac{T_{2s}}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \Rightarrow T_{2s} = 873K \left(\frac{100kPa}{2000kPa}\right)^{\frac{1.4-1}{1.4}} = 370.93K$

$\eta_t = \frac{h_1 - h_{2a}}{h_1 - h_{2s}} = \frac{C_p(T_1 - T_{2a})}{C_p(T_1 - T_{2s})} = \frac{T_1 - T_{2a}}{T_1 - T_{2s}} = 0.9 \Rightarrow$

$T_{2a} = T_1 - (T_1 - T_{2s}) \times 0.9 \doteq 421.14K$.

(b) $\Delta S_{1\text{-}2} = C_p \ln\frac{T_{2a}}{T_1} - R\ln\frac{P_2}{P_1} = 1\ kJ/kg{\cdot}K \ln\frac{421.14K}{873K} - 0.28\ kJ/kg{\cdot}K \cdot \ln\frac{100kPa}{2000kPa}$

$\doteq 0.1098\ kJ/kg{\cdot}K$

where $R = C_p - C_v = 0.28\ kJ/kg{\cdot}K$.

$S_{gen} = \Delta S_{1\text{-}2} = 0.1098\ kJ/kg{\cdot}K$, since turbine is adiabatic.

(c). $W_{comp,in} = W_{turb,out} \Rightarrow$

$h_{4a} - h_3 = h_1 - h_{2a}. \Rightarrow$

$C_p(T_{4a} - T_3) = C_p(T_1 - T_{2a}) \Rightarrow$

$T_{4a} = T_3 + T_1 - T_{2a} = 744.86K$

(d). $\eta_c = \left.\frac{C_p(T_{4s} - T_3)}{C_p(T_{4a} - T_3)}\right\} = 0.8 \Rightarrow T_{4s} = T_3 + 0.8 \times (T_{4a} - T_3) = 654.99K$

$\frac{P_{4s}}{P_3} = \left(\frac{T_{4s}}{T_3}\right)^{\frac{k}{k-1}} \Rightarrow P_{4s} = 1665.8\ kPa.$

$P_{4a} = P_{4s} = 1665.8\ kPa$.

(e). $\Delta S_{3\text{-}4} = C_p \ln\frac{T_{4a}}{T_3} - R\ln\frac{P_4}{P_3} = 1kJ/kg{\cdot}K \cdot \ln\frac{744.86K}{293K} - 0.28kJ/kg{\cdot}K \ln\frac{1665.8kPa}{100kPa}$

$= 0.1454\ kJ/kg{\cdot}K.$

$S_{gen} = \Delta S_{3\text{-}4} = 0.1454\ kJ/kg{\cdot}K$, since the compressor is adiabatic.

2. For liquid, $v = const$

$$Tds = du + pdv = c dT \text{ , isentropic} \Rightarrow ds = 0 \Rightarrow dT = 0 \Rightarrow T_{2s} = T_1$$

$$\left\{ \begin{array}{l} T_{2s} = T_1 \\ s_{2s} = s_1 \end{array} \right. \Rightarrow \text{the same state}$$

$$\Rightarrow \quad \cancel{h_{2s}} + \frac{V_2^2}{2} - \cancel{h_1} - \frac{V_1^2}{2} = \dot{w}_s = 0.01787 \text{ kJ/kg.}$$

$$\Rightarrow \quad \dot{w}_a = \dot{w}_s \cdot \eta_t = 0.01698 \text{ kJ/kg·K.}$$