1. [50 points] A Rankine cycle plant is to produce a net of 100 MW shaft power. The actual turbine has an energy loss due to heat transfer of 2.5 MW. The actual pump has an energy loss due to heat transfer of 15 kW. Use data in the attached table to find the following:
   - The steam/water mass flow rate, in kg/s.
   - The plant energy efficiency.
   - The rates of energy generation for the pump and for the turbine.

<table>
<thead>
<tr>
<th>State</th>
<th>p, bar</th>
<th>T, C</th>
<th>x</th>
<th>h, kJ/kg</th>
<th>s, kJ/kg-K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>45.8</td>
<td>0.0</td>
<td>192</td>
<td>0.64926</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>46</td>
<td>n/a</td>
<td>196</td>
<td>0.64992</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>600</td>
<td>n/a</td>
<td>3670</td>
<td>7.3687</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
<td>45.8</td>
<td>0.9</td>
<td>2460</td>
<td>7.7733</td>
</tr>
</tbody>
</table>
\[ \eta_{\text{plant}} = \frac{\text{Wnet}}{\text{Q}_{\text{in}}} = \frac{102.5 \text{ MW}}{(3670 - 19\% \times 84.7/1000} = 35.1\% \]

\[ \delta_+ = 84.7 \left(7.7733 - 7.3687\right) - \frac{(-2.5 \times 1000)}{(273 + 85)} = + 42.4 \text{ kW} \]

\[ \delta_p = 84.7 \left(0.64992 - 0.64926\right) - \frac{(-15)}{(300)} = + 0.104 \text{ kW} \]
2. [50 points] An IC engine undergoes a five step cycle.
   a. The first step is reversible and adiabatic compression from 1 bar and 300 K where the compression ratio is 8:1.
   b. The second step is a constant volume heat addition until the temperature reaches 1000 K.
   c. The third step is constant pressure heat addition until the volume increases by 50%.
   d. The fourth step is reversible and adiabatic expansion until the specific volume is the same as that for the initial state.
   e. Constant volume heat rejection completes the cycle.

Use the table data below to compute the following the cycle efficiency.

<table>
<thead>
<tr>
<th>State</th>
<th>p, bar</th>
<th>T, K</th>
<th>u, kJ/kg</th>
<th>h, kJ/kg</th>
<th>s, kJ/kg-K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>300</td>
<td>214</td>
<td>301</td>
<td>5.7062</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>674</td>
<td>492</td>
<td>686</td>
<td>5.7062</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>1000</td>
<td>760</td>
<td>1047</td>
<td>6.3129</td>
</tr>
<tr>
<td>4</td>
<td>9.91</td>
<td>1500</td>
<td>1206</td>
<td>1636</td>
<td>6.7899</td>
</tr>
<tr>
<td>5</td>
<td>4.03</td>
<td>1208</td>
<td>941</td>
<td>1287</td>
<td>6.7899</td>
</tr>
</tbody>
</table>

\[
\text{System: } \Sigma v \text{ in cylinder psi/cyl! For all steps: } q-e, \ Z=1 \text{ ideal gas; } \Delta p, \ \Delta v < 0 \]

\[
\begin{align*}
\sum m &= \frac{dm}{dt} + \sum \frac{dm}{dt} \\
&= m \text{ constant}
\end{align*}
\]

\[
\begin{align*}
\Sigma m(h+ke+pe) + Q - W &= \frac{\partial E}{\partial t} \bigg|_{\text{sys}} \\
&+ \sum m(h+ke+pe) \\
\Rightarrow Q - W &= \frac{\partial E}{\partial t} \bigg|_{\text{sys}}
\end{align*}
\]

\[
(W - W = \frac{\Delta E}{\Delta t})dt \Rightarrow Q - W = \Delta E = \Delta U + \Delta ke + \Delta pe
\]

\[Q = \Delta U + W\]
\[ \eta_{\text{cycle}} = \frac{W_{\text{net}}}{Q_{\text{in}}} = \frac{-W_{\text{L}} + W_{\text{q}} + W_{\text{t}}}{Q_{\text{34}}} = \frac{Q_{\text{net}}}{Q_{\text{in}}} = \frac{Q_{\text{in}} - Q_{\text{out}}}{Q_{\text{in}}} \]

\[ \eta_{\text{cycle}} = \frac{Q_{\text{23}} + Q_{\text{34}}}{Q_{\text{23}} + Q_{\text{34}}} = \frac{W_{\text{23}} = 0}{Q_{\text{23}}} = \frac{W_{\text{51}} = 0}{Q_{\text{51}}} = \frac{W_{\text{q}} = pA}{Q_{\text{34}}} = \eta_{\text{34}} = \frac{\text{A} \text{H}_{\text{34}}}{Q_{\text{34}}} \]

\[ \eta_{\text{cycle}} = \frac{(u_{3} - u_{2}) + (h_{4} - h_{13}) - (u_{9} - u_{4})}{(u_{3} - u_{2}) + (h_{4} - h_{13})} = \frac{(7.6 - 4.5) + (1086 - 1047) - (9.1 - 2)}{(7.6 - 4.5) + (1086 - 1047)} \]

\[ = \frac{130}{857} = 15.2\% \]