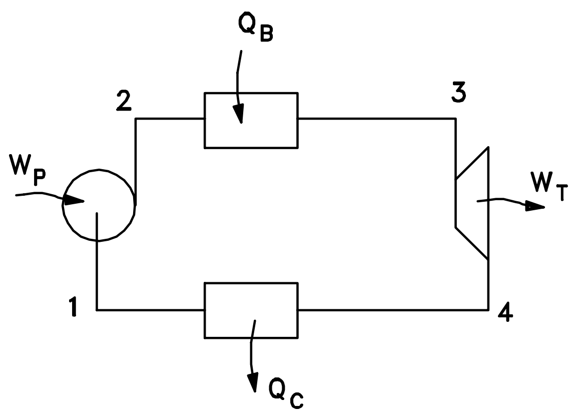
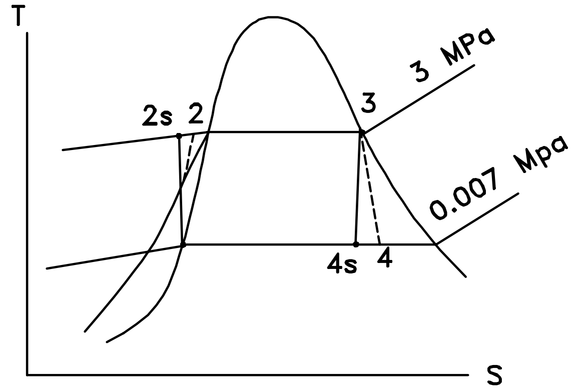
Problem: 9-21

Given: Simple Rankine cycle with saturated liquid at 0.007 MPa at pump inlet.
Saturated vapour at 3 MPa at turbine inlet
Pump efficiency: 60%
Turbine efficiency: 80%

Find: The overall thermal efficiency

Assume: Incompressible at state 1





$\underline{1 \rightarrow 2}$
From steam tables:

$$
\begin{aligned}
h_1 &= 162.7 \ kJ/kg \\
\nu_1 &= 0.001007 \ m^3/kg
\end{aligned}
$$

$$
\begin{aligned}
h_{2s} &= h_1 + \nu(P_2 - P_1) \\
W_{ps} &= h_{2s} - h_1 \\
&= \nu(P_2 - P_1) \\
&= (0.001007 \ m^3/kg)(3000 - 7) \ kN/m^2 \\
&= 3.01 \ kJ/kg \\
W_p &= \frac{W_{ps}}{\eta_s} = \frac{3.01 \ kJ/kg}{0.6} = 5.02 \ kJ/kg \\
h_2 &= h_1 + W_p = 162.7 + 5.02 = 167.7 \ kJ/kg
\end{aligned}
$$

$\underline{2 \to 3}$
From steam tables

$$\begin{aligned} h_3 &= 2804.1\ kJ/kg \\ s_3 &= 6.1878\ kJ/kg \cdot K \\ Q_B &= h_3 - h_2 = 2904.1 - 167.7 = 2636.4\ kJ/kg \end{aligned}$$

$\underline{3 \to 4}$
consider isotropic case

$$\begin{aligned} s_{4s} &= s_3 = 6.1878\ kJ/kg \cdot K \\ p_4 &= 0.007\ MPa \end{aligned}$$

find quality

$$x = \frac{s_{4s} - s_{f4s}}{s_{g4s} - s_{f4s}} = 0.729$$

from quality $h_{4s} = 1919.4\ kJ/kg$

$$\begin{aligned} W_{T_s} &= h_3 - h_4 s = 2304.1 - 1919.4 = 884.7\ kJ/kg \\ W_T &= \eta_s W_{T_s} = 0.8(884.7) = 707.8\ kJ/kg \end{aligned}$$

<u>Overall</u>

$$\begin{aligned} \eta_T &= \frac{W_T - W_p}{Q_B} \\ &= \frac{707.8 - 5.02}{2636.4} \\ &= \boxed{26.7\%} \end{aligned}$$