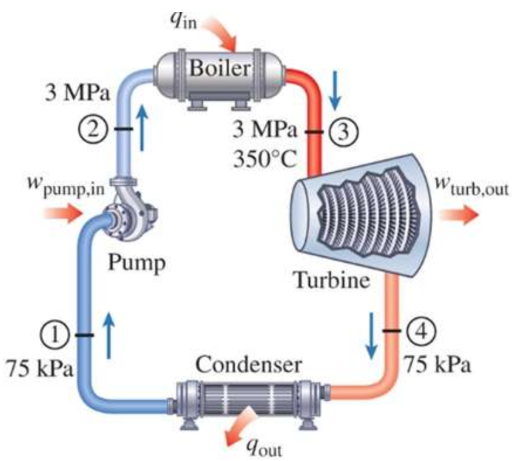
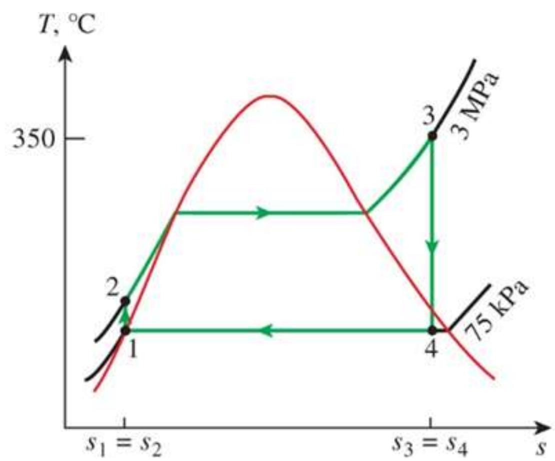
Given:
Consider a steam power plant operating on the simple ideal Rankine cycle. Steam enters the turbine at 3 MPa and 350°C and is condensed in the condenser at a pressure of 75 kPa.

$P_3 := 3\ \text{MPa}$ $\quad T_3 := 350\ °\text{C}$ $\quad P_4 := 75\ \text{kPa}$





Required:
Determine the thermal efficiency.

Solution:
At state 1, the pressure will be the same as state 4 and a saturated liquid.

$$P_1 := P_4 = 75.00\ \text{kPa} \qquad x_1 := 0$$

Going to Table A-5 @ $P_1 = 75.00\ \text{kPa}$ and $x_1 = 0$ shows

$$h_1 := 384.44\ \frac{\text{kJ}}{\text{kg}} \qquad v_1 := 0.001037\ \frac{\text{m}^3}{\text{kg}} \qquad T_1 := 91.76\ °\text{C}$$

At state 2, the pressure will be the same as state 3 and will have the same entropy as state 1.

$$P_2 := P_3 = 3.000\ \text{MPa}$$

The specific work of the pump when using an incompressible fluid may then be determined by

$$w_p := v_1 \cdot \left(P_2 - P_1\right) = 3.033\ \frac{\text{kJ}}{\text{kg}}$$

It is also known that the specific work of the pump is given by

$$w_p = h_2 - h_1$$

The specific enthalpy at state 2 may then be found by

$$h_2 := w_p + h_1 = 387.5\ \frac{\text{kJ}}{\text{kg}}$$

Going to Table A-4 @ $T_3 = 350.0\ °\text{C}$ and $P_3 = 3000\ \text{kPa}$ shows that the state is superheated. Going to Table A-6 @ $T_3 = 350.0\ °\text{C}$ and $P_3 = 3.000\ \text{MPa}$ shows

$$h_3 := 3116.1\ \frac{\text{kJ}}{\text{kg}} \qquad s_3 := 6.7450\ \frac{\text{kJ}}{\text{kg K}}$$

Solution (contd.):
At state 4, the entropy will be the same as state 3.

$$s_4 := s_3 = 6.745 \ \frac{\text{kJ}}{\text{kg K}}$$

Going to Table A-5 @ $P_4 = 75.00 \ \text{kPa}$ and $s_4 = 6.745 \ \frac{\text{kJ}}{\text{kg K}}$ shows the state is in the two phase region.

$$s_f := 1.2132 \ \frac{\text{kJ}}{\text{kg K}} \qquad s_g := 7.4558 \ \frac{\text{kJ}}{\text{kg K}} \qquad h_f := 384.44 \ \frac{\text{kJ}}{\text{kg}} \qquad h_g := 2662.4 \ \frac{\text{kJ}}{\text{kg}}$$

$$x_4 := \frac{s_4 - s_f}{s_g - s_f} = 0.8861 \qquad h_4 := h_f + x_4 \cdot \left(h_g - h_f\right) = 2403 \ \frac{\text{kJ}}{\text{kg}}$$

The specific heat rejected by the cycle is then

$$q_{out} := h_4 - h_1 = 2019 \ \frac{\text{kJ}}{\text{kg}}$$

The specific heat added to the cycle is then

$$q_{in} := h_3 - h_2 = 2729 \ \frac{\text{kJ}}{\text{kg}}$$

The thermal efficiency of the cycle is then given by

$$\boxed{\eta_{th} := 1 - \frac{q_{out}}{q_{in}} = 26.02 \ \%}$$

Alternatively, the thermal efficiency of the cycle could have been found by calculating the specific work of the turbine. This is shown below.

$$w_t := h_3 - h_4 = 713.1 \ \frac{\text{kJ}}{\text{kg}}$$

The net work is then

$$w_{net} := w_t - w_p = 710.0 \ \frac{\text{kJ}}{\text{kg}}$$

The thermal efficiency may then be found by

$$\eta_{th} := \frac{w_{net}}{q_{in}} = 26.02 \ \%$$

The Carnot efficiency may also be calculated.

$$\eta_{th,rev} := 1 - \frac{T_1}{T_3} = 41.44 \ \%$$