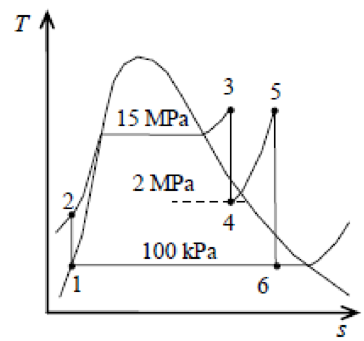
# Applied Thermodynamics
# Tutorial 3(17.8.2016) Solution

**Q.1**

***Assumptions*** **1** Steady operating conditions exist. **2** Kinetic and potential energy changes are negligible.

***Analysis*** From the steam tables (Tables A-4, A-5, and A-6 or EES),

$$h_1 = h_{f@100\,\text{kPa}} = 417.51\ \text{kJ/kg}$$
$$v_1 = v_{f@100\,\text{kPa}} = 0.001043\ \text{m}^3/\text{kg}$$




$$\begin{aligned} w_{\text{p,in}} &= v_1(P_2 - P_1) \\ &= (0.001043\ \text{m}^3/\text{kg})(15000 - 100)\text{kPa}\left(\frac{1\ \text{kJ}}{1\ \text{kPa}\cdot\text{m}^3}\right) \\ &= 15.54\ \text{kJ/kg} \end{aligned}$$
$$h_2 = h_1 + w_{\text{p,in}} = 417.51 + 15.54 = 433.05\ \text{kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 15{,}000\ \text{kPa} \\ T_3 = 450°\text{C} \end{array}\right\} \begin{array}{l} h_3 = 3157.9\ \text{kJ/kg} \\ s_3 = 6.1434\ \text{kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_4 = 2000\ \text{kPa} \\ s_4 = s_3 \end{array}\right\} \begin{array}{l} x_4 = \dfrac{s_4 - s_f}{s_{fg}} = \dfrac{6.1434 - 2.4467}{3.8923} = 0.9497 \\ h_4 = h_f + x_4 h_{fg} = 908.47 + (0.9497)(1889.8) = 2703.3\ \text{kJ/kg} \end{array}$$

$$\left.\begin{array}{l} P_5 = 2000\ \text{kPa} \\ T_5 = 450°\text{C} \end{array}\right\} \begin{array}{l} h_5 = 3358.2\ \text{kJ/kg} \\ s_5 = 7.2866\ \text{kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_6 = 100\ \text{kPa} \\ s_6 = s_5 \end{array}\right\} \begin{array}{l} x_6 = \dfrac{s_6 - s_f}{s_{fg}} = \dfrac{7.2866 - 1.3028}{6.0562} = 0.9880 \\ h_6 = h_f + x_6 h_{fg} = 417.51 + (0.9880)(22257.5) = 2648.0\ \text{kJ/kg} \end{array}$$

Thus,

$$q_{\text{in}} = (h_3 - h_2) + (h_5 - h_4) = 3157.9 - 433.05 + 3358.2 - 2703.3 = 3379.8\ \text{kJ/kg}$$
$$q_{\text{out}} = h_6 - h_1 = 2648.0 - 417.51 = 2230.5\ \text{kJ/kg}$$
$$w_{\text{net}} = q_{\text{in}} - q_{\text{out}} = 379.8 - 2230.5 = 1149.2\ \text{kJ/kg}$$

The power produced by the cycle is

$$\dot{W}_{\text{net}} = \dot{m} w_{\text{net}} = (1.74\ \text{kg/s})(1149.2\ \text{kJ/kg}) = \mathbf{2000\,kW}$$

The rate of heat transfer in the rehetaer is

$$\dot{Q}_{\text{reheater}} = \dot{m}(h_5 - h_4) = (1.740\ \text{kg/s})(3358.2 - 2703.3)\ \text{kJ/kg} = \mathbf{1140\,kW}$$
$$\dot{W}_{\text{P,in}} = \dot{m} w_{\text{P,in}} = (1.740\ \text{kg/s})(15.54\ \text{kJ/kg}) = \mathbf{27\,kW}$$

and the thermal efficiency of the cycle is

$$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{2230.5}{3379.8} = \mathbf{0.340}$$

**Q. 2**

*Assumptions* **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work interactions. **4** The device is adiabatic and thus heat transfer is negligible.

*Properties* From the steam tables (Tables A-4 through A-6 or EES),

$$h_1 \cong h_{f@\,40°\mathrm{C}} = 167.53 \text{ kJ/kg}$$

$$\left.\begin{array}{l} P_2 = 200\,\text{kPa} \\ T_2 = 150°\text{C} \end{array}\right\} h_2 = 2769.1\,\text{kJ/kg}$$

$$h_3 \cong h_{f@\,110°\mathrm{C}} = 461.42 \text{ kJ/kg}$$

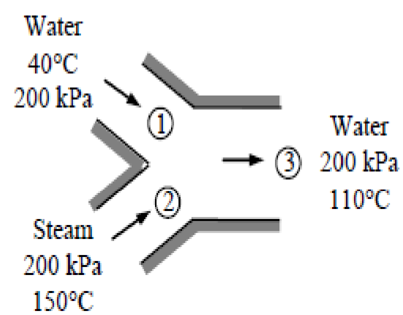
*Analysis* We take the mixing chamber as the system, which is a control volume since mass crosses the boundary. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance:

$$\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta\dot{m}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0$$

$$\dot{m}_{\text{in}} = \dot{m}_{\text{out}}$$

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$$




Energy balance:

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta\dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,}\\ \text{potential, etc. energies}}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \quad (\text{since } \dot{Q} = \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$$

Solving for the bleed steam mass flow rate to the inlet feedwater mass flow rate, and substituting gives

$$\frac{\dot{m}_2}{\dot{m}_1} = \frac{h_1 - h_3}{h_3 - h_2} = \frac{(167.53 - 461.42)\text{ kJ/kg}}{(461.42 - 2769.1)\text{ kJ/kg}} = \mathbf{0.127}$$

**Q.3 Moisture content remains the same, everything else decreases.**

**Q. 4 Both cycles would have the same efficiency.**