As shown in Fig. P.5.17, a reversible power cycle receives energy $Q_H$ by heat transfer from a hot reservoir at $T_H$ and rejects energy $Q_C$ by heat transfer to a cold reservoir at $T_C$.

**a.** If $T_H = 1600$ K and $T_C = 400$ K, what is the thermal efficiency?

**b.** If $T_H = 500$°C, $T_C = 20$°C, and $W_{\text{cycle}} = 1000$ kJ, what are $Q_H$ and $Q_C$, each in kJ?

**c.** If $\eta = 60\%$ and $T_C = 40$°F, what is $T_H$, in °F?

**d.** If $\eta = 40\%$ and $T_H = 727$°C, what is $T_C$, in °C?

Figure P.5.60 gives the schematic of a vapor power plant in which water steadily circulates through the four components shown. The water flows through the boiler and condenser at constant pressure and through the turbine and pump adiabatically. Kinetic and potential energy effects can be ignored. Process data follow:

**Process 4–1:** constant pressure at 1 MPa from saturated liquid to saturated vapor

**Process 2–3:** constant pressure at 20 kPa from $x_2 = 88\%$ to $x_3 = 18\%$

\[
\eta = \frac{W_{\text{cycle}}}{Q_H} = 1 - \frac{Q_C}{Q_H} \tag{5.4}
\]

\[
\eta_{\text{max}} = 1 - \frac{T_C}{T_H} \tag{5.9}
\]

\[
\int \left( \frac{\delta Q}{T} \right)_b = -\sigma_{\text{cycle}} \tag{5.13}
\]
a. Using Eq. 5.13 expressed on a time-rate basis, determine if the cycle is *internally reversible*, *irreversible*, or *impossible*.

b. Determine the thermal efficiency using Eq. 5.4 expressed on a time-rate basis and steam table data.

c. Compare the result of part (b) with the *Carnot efficiency* calculated using Eq. 5.9 with the boiler and condenser temperatures and comment.

6.4 Using the appropriate tables, determine the change in specific entropy between the specified states, in Btu/lb · °R. Show the states on a sketch of the $T$–$s$ diagram.

a. water, $p_1 = 10$ lbf/in.$^2$, saturated vapor; $p_2 = 500$ lbf/in.$^2$, $T_2 = 700^\circ$F.

b. ammonia, $p_1 = 140$ lbf/in.$^2$, $T_1 = 160^\circ$F; $T_2 = -10^\circ$F, $h_2 = 590$ Btu/lb.

c. air as an ideal gas, $T_1 = 80^\circ$F, $p_1 = 1$ atm; $T_2 = 340^\circ$F, $p = 5$ atm.

d. oxygen as an ideal gas, $T_1 = T_2 = 520^\circ$R, $p_1 = 10$ atm, $p_2 = 5$ atm.
A refrigeration cycle is used to keep a refrigerated space at -15°C. The refrigeration fluid is R134a. The condenser pressure is 1.4 MPa and the evaporator pressure is 0.10 MPa. The temperature of the fluid at the condenser exit is 48°C and the fluid is a compressed liquid. At the compressor inlet, the temperature is -20°C and the fluid is a superheated vapor. The isentropic efficiency of the compressor is 80% and the actual compressor power is 20 kW.

(a) Sketch the cycle on a T-s diagram.
(b) Calculate the rate of heat removal from the refrigerated space, in kW.
(c) Find the COP for the cycle.

Answer: (c) COP=1.66
The system sketch below shows a plant to produce power and to generate heat for building space heating. Saturated liquid water at 10 bar (State 1) flowing steadily at the rate of 1.5 kg/s is compressed to 60 bar (State 2) by a pump with an efficiency of 86.7%. The work needed by an isentropic pump is \( w_s = -\int v \, dP \). Water leaving the pump is heated in the boiler to become steam at 60 bar and 600\(^\circ\)C (State 3) at the exit. The plant is to produce power while heating the building to 20\(^\circ\)C by the heater. One-third of the steam leaving the boiler is throttled to a pressure of 10 bar (State 4) and is routed to the heater. The rest of the steam is expanded in an isentropic turbine to a pressure of 10 bar (State 5) and steam exiting the turbine is also routed to the heater. Do not interpolate; use the closest table values.
(a) Complete the table below. You must show any necessary work to receive full credit.

<table>
<thead>
<tr>
<th>State</th>
<th>p (bar)</th>
<th>T (°C)</th>
<th>v (m³/kg)</th>
<th>h (kJ/kg)</th>
<th>s (kJ/kg·K)</th>
</tr>
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<td>5 = 5s</td>
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</tr>
</tbody>
</table>

(b) Find the power needed by the pump, in kW.
(c) Determine the power produced by the turbine, in kW.
(d) Find the heat transfer from the heater to the building space, in kW.
(e) Calculate the entropy production for the heater, in kW/K.
(f) Show the isentropic and actual processes on T-s diagram. Label all the states and draw constant pressure lines.

Answer: (b) -9.75 kW