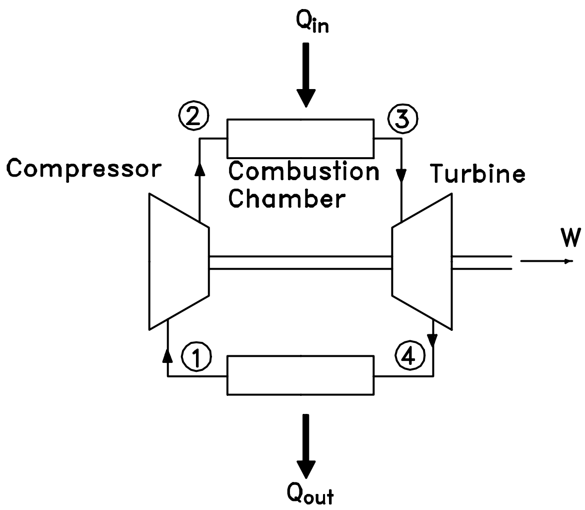
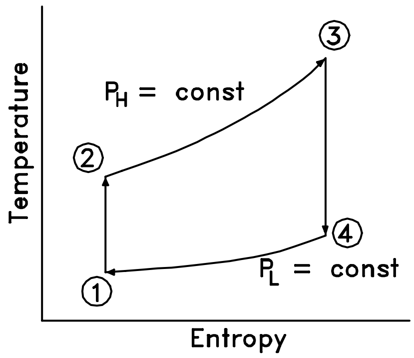
Problem: 7-3

Given: A simple gas turbine engine operates with air as the working fluid, a pressure ratio of 18:1 and a maximum temperature of 700 $°C$. The air enters the compressor at 100 kPa, $20°C$.

Find: The thermal efficiency, the specific heat addition and the state of air exhausted by the turbine when it is modeled by the Brayton cycle.

Assume: Constant specific heats.





The thermal efficiency is determined by the pressure ratio and the properties of the working fluid,

$$\begin{aligned}\eta &= 1 - \frac{1}{f_p^{(k-1)/k}} \\ &= 1 - \frac{1}{18^{0.4/1.4}} \\ &= 0.562\end{aligned}$$

Applying the isentropic process relationships for an ideal gas with constant specific heats to the compressor, we obtain T_2

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$

$$= 669\ K$$

The heat added to the combustion chamber per unit of flow through this chamber is found by applying the first law

$$\frac{Q_{23}}{m} + \frac{\cancel{W_{23}}^{\,0}}{m} = h_3 - h_2$$

When specialized to the combustion chamber, this becomes

$$\begin{aligned} \frac{Q_{23}}{m} &= c_p(T_3 - T_2) \\ &= 1.0035(973 - 669) \\ &= 305.1\ kJ/kg \end{aligned}$$

Applying the isentropic process relationships to the turbine expansion

$$\begin{aligned} T_4 &= T_3 \left(\frac{P_4}{P_3}\right)^{(k-1)/k} \\ &= 973 \left(\frac{1}{18}\right)^{0.4/1.4} \\ &= 426\ K \end{aligned}$$

and the pressure at the turbine outlet matches the 100 kPa pressure at the compressor inlet.