UBC MECH327 Assignment 4 Q5

Air enters an insulated compressor at 1.05 bar and 23°C at rate of 1.8 kg/s and exits at 2.9 bar. Assuming that the compressor is operating at steady state, and that the changes in kinetic and potential energy can be neglected:

(a) What is the minimum theoretical power input required for compression and what is the associated outlet temperature?

$P_1 = 1.05$ bar, $T_1 = 23°C = 296$ K, $P_2 = 2.9$ bar.

With reference to Example 7-13 p.367 and the Isentropic formula 7-57a p.365, with $k = 1.4$ and $(k-1)/k = 0.2857$:

$$w_{comp,in} = \frac{kRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(k-1)/k} - 1\right] = \frac{0.287 \times 296}{0.2857}\left[\left(\frac{2.9}{1.05}\right)^{0.2857} - 1\right] = 100.134 \text{ kJ/kg}.$$

Also, $w_{comp,in} = \dfrac{kR(T_2 - T_1)}{k-1}$, $\quad T_2 = \dfrac{w_{comp,in}(k-1)}{kR} + T_1 = \dfrac{100.134 \times 0.2857}{0.287} + 296 = 395.68 \text{ K} = 123°\text{C}.$

(b) If the isentropic compressor efficiency is η_c=80%, what is the required power input and what is the outlet temperature?

$$\eta_C = \frac{w_{comp,in}}{w_{actual,in}}, \quad w_{actual,in} = \frac{w_{comp,in}}{\eta_C} = \frac{100.134}{0.80} = 125.168 \text{ kJ/kg}.$$

$$T_2 = \frac{125.168 \times 0.2857}{0.287} + 296 = 420.60 \text{ K} = 148°\text{C}.$$