Given and Required: $kJ := 1000J$

Assuming a compressor efficiency of 80% and a turbine efficiency of 85%, determine the back work ratio, thermal efficiency, and the exit temperature of the Brayton gas-turbine cycle used in the previous problem.

$\eta_c := 80\%$ $\eta_t := 85\%$

Solution:

From the previous problem, the specific work of the compressor and turbine in the isentropic cases were found to be

$w_{cs} := 243.99 \frac{kJ}{kg}$ $w_{ts} := 606.584 \frac{kJ}{kg}$

From the previous problem, the specific enthalpy at state 1 and state 3 were found to be

$h_1 := 300.19 \frac{kJ}{kg}$ $h_3 := 1395.97 \frac{kJ}{kg}$

Using the efficiencies given, the actual work of the compressor and turbine may be found

$w_{ca} := \frac{w_{cs}}{\eta_c} = 304.988 \cdot \frac{kJ}{kg}$ $w_{ta} := \eta_t \cdot w_{ts} = 515.596 \cdot \frac{kJ}{kg}$

The back work ratio is then found by

$$\boxed{r_{bw} := \frac{w_{ca}}{w_{ta}} = 0.5915}$$

It should be mentioned that for the ideal Brayton cycle, the back work ratio was 0.402 (found in previous problem). The increase seen in the calculation above is a result of irreversibilities in the turbine and compressor.

The actual thermal efficiency is given by

$$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{w_{out} - w_{in}}{h_3 - h_{2a}} = \frac{w_{ta} - w_{ca}}{h_3 - h_{2a}}$$

The actual specific enthalpy at state 2 may be found by

$h_{2a} := h_1 + w_{ca} = 605.178 \cdot \frac{kJ}{kg}$ $(h_{2a} - h_1 = w_{ca})$

Thus the actual thermal efficiency is found to be

$$\boxed{\eta_{th} := \frac{w_{ta} - w_{ca}}{h_3 - h_{2a}} = 26.6 \cdot \%}$$

Again it should be mentioned that for the ideal Brayton cycle, the thermal efficiency was 42.6%. The decrease seen in the calculation above is a result of the efficiencies of the turbine and compressor.

The actual specific enthalpy at state 4 may be found by

$h_{4a} := h_3 - w_{ta} = 880.374 \cdot \frac{kJ}{kg}$ $(h_3 - h_{4a} = w_{ta})$

Solution (contd.):

Going to Table A-17 @ $h_{4a} = 880.374 \cdot \frac{kJ}{kg}$ shows that interpolation is needed.

$h_a := 866.08 \frac{kJ}{kg}$ $h_b := 888.27 \frac{kJ}{kg}$

$T_a := 840K$ $T_b := 860K$

$$\boxed{T_{4a} := \frac{h_{4a} - h_a}{h_b - h_a} \cdot \left(T_b - T_a\right) + T_a = 852.9\,K}$$