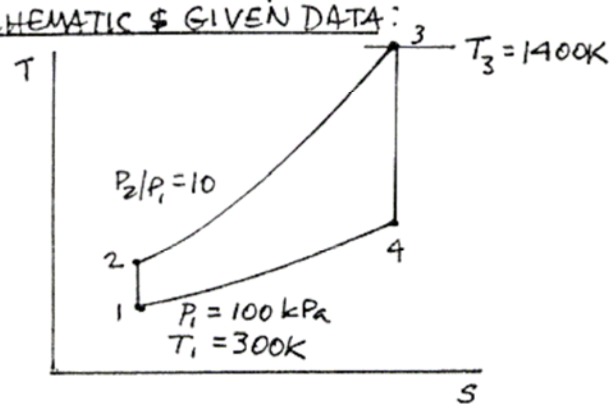
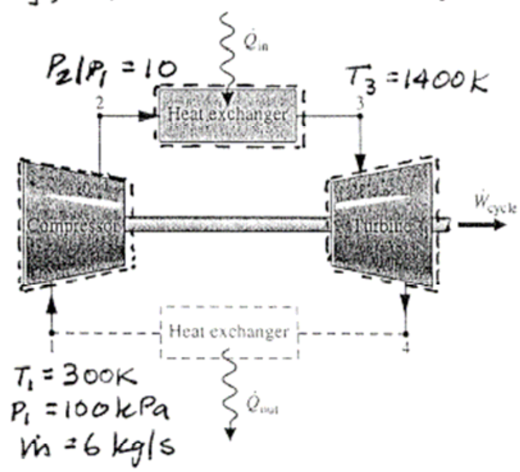
PROBLEM 9.41

KNOWN: Air enters a cold air-standard ideal Brayton cycle with a given flow rate and at a specified state. The compressor pressure ratio and maximum cycle temperature are known.

FIND: Determine (a) the thermal efficiency, (b) the back work ratio, and (c) the net power.

SCHEMATIC & GIVEN DATA:





ENGINEERING MODEL: See Example 9.4.
Also, assume $k = 1.4$ and $c_p = 1.005\ kJ/kg \cdot K$.

ANALYSIS: First, determine T_2 and T_4, as follows:

(Eq. 9.23) $T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = (300)(10)^{\frac{1.4-1}{1.4}} = 579.2\ K$

(Eq. 9.24) $T_4 = T_3 \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = (1400)\left(\frac{1}{10}\right)^{\frac{1.4-1}{1.4}} = 725.13\ K$

(a) To evaluate thermal efficiency, use

$$\eta = 1 - \frac{\dot{Q}_{out}}{\dot{Q}_{in}}$$

$\dot{Q}_{in}$: $\dot{Q}_{in} = \dot{m}(h_3 - h_2) = \dot{m} c_p (T_3 - T_2)$
$= (6\ kg/s)(1.005\ \frac{kJ}{kg \cdot K})(1400 - 579.2)K = 4949.4\ kJ/s$

$\dot{Q}_{out}$: $\dot{Q}_{out} = \dot{m}(h_4 - h_1) = \dot{m} c_p (T_4 - T_1) = (6)(1.005)(725.13 - 300) = 2563.5\ \frac{kJ}{s}$

Thus $\eta = 1 - \frac{\dot{Q}_{out}}{\dot{Q}_{in}} = 1 - \frac{2563.5}{4949.4} = 0.482\ (48.2\%)$ ← η

(b) The back work ratio is $bwr = \dot{W}_c / \dot{W}_t$

$\dot{W}_c = \dot{m}(h_2 - h_1) = \dot{m} c_p (T_2 - T_1) = (6)(1.005)(579.2 - 300)$
$= 1683.6\ kJ/s$

$\dot{W}_t = \dot{m}(h_3 - h_4) = \dot{m} c_p (T_3 - T_4) = (6)(1.005)(1400 - 725.13) = 4069.5\ \frac{kJ}{s}$

and $bwr = \dot{W}_c / \dot{W}_t = \frac{1683.6}{4069.5} = 0.4137$ ← bwr

(c) The net power developed is

$\dot{W}_{cycle} = \dot{W}_t - \dot{W}_c = (4069.5 - 1683.6)\ \frac{kJ}{s} \left| \frac{1\ kW}{1\ kJ/s} \right| = 2385.9\ kW$ ← $\dot{W}_{cycle}$