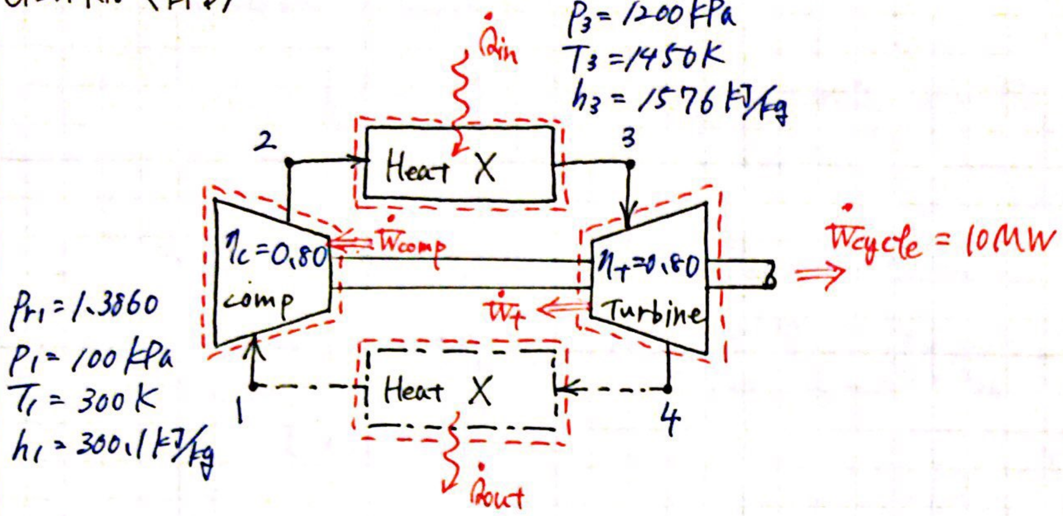
GIVEN: <EFD>



FIND: (a) P, in kPa, T, in K, & h, in kJ/kg @ each principle state

(b) $\dot{m}$ of air, kg/s

(c) $\dot{Q}_{in}$, in kW

(d) η_{TH}, in %

ASSUMP: SSSF, 1-DUF, $\Delta PE = \Delta KE = 0$, open sys.
neglect pressure loss in combustor
$\Delta s \neq 0$ compressor and turbine, air standard cycle

EQN: $\cancel{\frac{dm}{dt}\Big|_{sys}}^{0} = \sum_i \dot{m} - \sum_e \dot{m}$, $\cancel{\frac{dE}{dt}\Big|_{sys}}^{0} = \dot{Q} - \dot{W} + \sum_i \dot{m}(h + \cancel{pe}^{0} + \cancel{ke}^{0}) - \sum_e \dot{m}(h + \cancel{pe}^{0} + \cancel{ke}^{0})$

$\cancel{\frac{ds}{dt}\Big|_{sys}}^{0} = \sum \frac{\dot{Q}}{T} + \sum_i \dot{m} s_i - \sum_e \dot{m} s_e + \dot{\sigma}_{gen}$, $P\forall = mRT$ $R = 0.287\ \frac{kJ}{kg\text{-}K}$

SOLN:
(a)

<state 2> From assumption of no P-loss for combustor

$$P_2 = P_3 = 1200\,kPa \qquad \boxed{P_2 = 1200\,kPa}$$

if compresson is isentropic

$$\frac{P_{r2}}{P_{r1}} = \frac{P_2}{P_1} \Leftrightarrow P_{r2} = \frac{1200\,kPa}{100\,kPa}\cdot(1.3860) = 16.632$$

then find the corresponding h_{2s} by interpolation @ P_{r2}

$$h_{2s} = (P_{r2} - P_r|_{T=600K})\cdot\frac{h|_{T=610K} - h|_{T=600K}}{P_r|_{T=610K} - P_r|_{T=600K}} + h|_{T=600K}$$

$$= (16.632 - 16.28)\frac{617.7\,kJ/kg - 607.2\,kJ/kg}{17.30 - 16.28} + 607.2\,kJ/kg \simeq 610.82\,kJ/kg$$

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now since $\eta_c = 0.80$,

$$h_2 = \frac{1}{\eta_c}(h_{2s} - h_1) + h_1 = \frac{1}{0.80}(610.8\,kJ/kg - 300.1\,kJ/kg) + 300.1\,kJ/kg$$
$$\cong 688.48$$

$$\boxed{h_2 = 688.5\,kJ/kg}$$

then the corresponding temp. is by interpolation

$$T_2 = (688.5\,kJ/kg - 681.3\,kJ/kg)\frac{680K - 670K}{691.9\,kJ/kg - 681.3\,kJ/kg} + 670K$$
$$\cong 676.79\,K$$

$$\boxed{T_2 = 677\,K}$$

⟨state 4⟩ first find P_{r3} using interpolation

$$P_{r3} = (1450K - 1440K)\frac{537.1 - 506.9}{1460K - 1440K} + 506.9 \cong 522.0$$

since $P_4 = P_1 = 100\,kPa$

$$\boxed{P_4 = 100\,kPa}$$

and, if isentropic ($\Delta s = 0$) turbine

$$P_{r4} = \frac{P_4}{P_3}P_{r3} = \frac{100\,kPa}{1200\,kPa}(522.0) = 43.50$$

now using interpolation

$$h_{4s} = (43.50 - 43.35)\frac{(810.9 - 800.0)\,kJ/kg}{45.50 - 43.35} + 800.0\,kJ/kg$$
$$\cong 800.8\,kJ/kg$$

since $\eta_T = 0.80$

$$h_4 = h_3 - \eta_T(h_3 - h_{4s}) = 1576\,kJ/kg - (0.80)(1576 - 800.8)\,kJ/kg$$
$$\cong 955.84\,kJ/kg$$

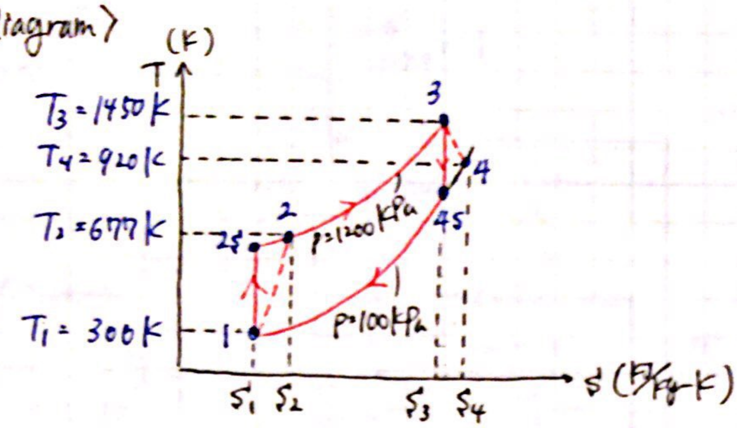
$$\boxed{h_4 = 955.8\,kJ/kg}$$

now from interpolation (just in case)

$$T_4 = (955.8\,kJ/kg - 955.4\,kJ/kg)\frac{930K - 920K}{(966.7 - 955.4)\,kJ/kg} + 920K \cong 920K$$

$$\boxed{T_4 = 920\,K}$$

⟨T-s diagram⟩



(b)

since we have all we need

for turbine

$$\dot{w}_{34} = h_3 - h_4 = 1576\ kJ/kg - 955.8\ kJ/kg \cong 620.2\ kJ/kg$$

for compressor

$$\dot{w}_{12} = h_1 - h_2 = 300.1\ kJ/kg - 688.5\ kJ/kg \cong -388.4\ kJ/kg$$

now $\dot{W}_{cycle} = \dot{m}(\dot{w}_{34} + \dot{w}_{12})$

$$\therefore \dot{m} = \frac{10 \times 10^3\ kW}{(620.2 - 388.4)\ kJ/kg} \cong 43.14\ kg/s \qquad \boxed{\dot{m} = 43.1\ kg/s}$$

(c)

for (2 → 3)

$$\dot{Q}_{23} = \dot{m}(h_3 - h_2)$$

$$= (43.1\ kg/s)(1576\ kJ/kg - 688.5\ kJ/kg)$$

$$\cong 38.25 \times 10^3\ kW$$

$$\boxed{\dot{Q}_{in} = 38.3 \times 10^3\ kW}$$

(d) finally

$$\eta_{TH} = \frac{\dot{W}_{cycle}}{\dot{Q}_{in}} = \frac{10 \times 10^3\ kW}{38.3 \times 10^3\ kW} \cong 0.2611$$

$$\boxed{\eta_{TH} = 26.1\%}$$