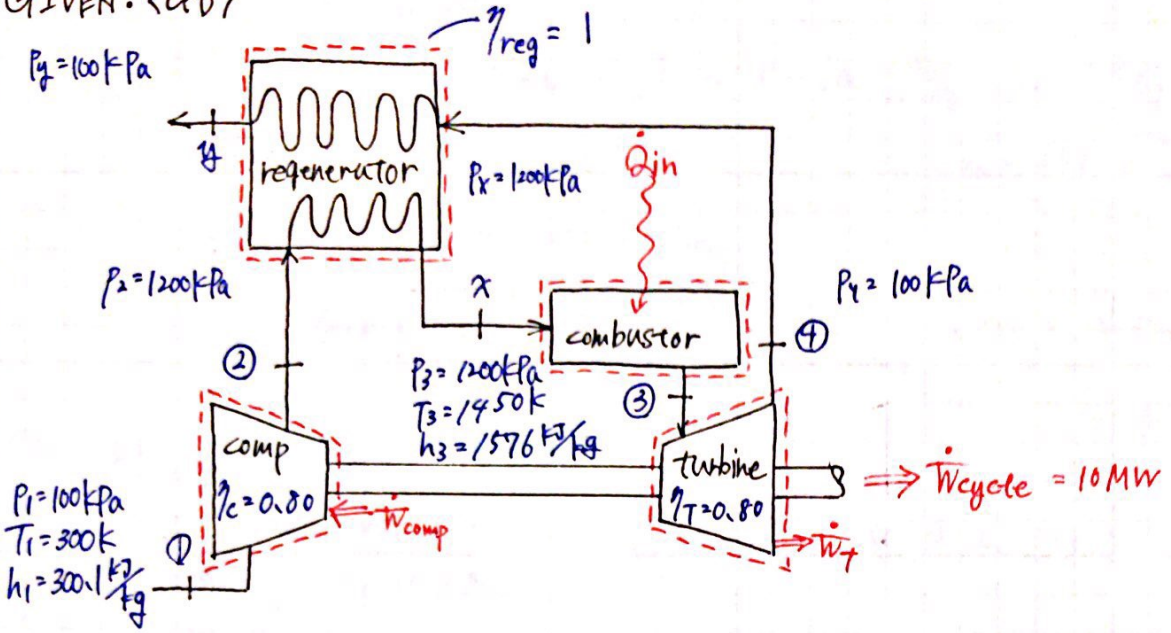
GIVEN: <CED>



FIND: (a) P, in kPa, T, in K, h, in kJ/kg for each state T-s diagram
(b) $\dot{m}$, in kg/s
(c) $\dot{Q}_{in}$ in kW
(d) η_{TH}, in %

ASSUMP: open sys., SSSF, 1-DUF, ideal gas, $\Delta PE = \Delta KE = 0$, air standard regenerative Brayton cycle, no pressure loss in combustor
$P_2 = P_x \cdot P_3$, $P_4 = P_1 = P_y$

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

SOLN:

(a)

<State 2> since $P_2 = 1200\,kPa$
if compressor was isentropic ($P_{r1} = 1.3860$)

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

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

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

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

$$\simeq 610.82\,kJ/kg$$

now since η_c is given

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

$h_2 = 688.5\ \text{kJ/kg}$

from interpolation the corresponding T_2 is

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

$T_2 = 677\,K$

〈state 4〉 find P_{r3} with interpolation

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

since $P_4 = P_1 = 100\,kPa$

if turbine is isentropic

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

with interpolation

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

since $\eta_T = 0.80$

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

$h_4 = 955.8\ \text{kJ/kg}$

now from approximation $T_4 \approx 920K$ (table)

$T_4 = 920\,K$

〈state x〉 from $\eta_{reg} = \frac{h_x - h_2}{h_4 - h_2} = 1$

$\Leftrightarrow h_x = h_4$

$h_x = 955.8\ \text{kJ/kg}$

and thus, $T_x = T_4$

$T_x = 920K$

〈state y〉 from 〈COE〉

$$0 = \cancel{\dot{Q}^{\,0}} - \cancel{\dot{W}^{\,0}} + \dot{m}(h_2 + h_4 - h_x - h_y)$$

$$h_y = h_2 + \cancel{h_4 - h_x} = 688.5\,\text{kJ/kg}$$

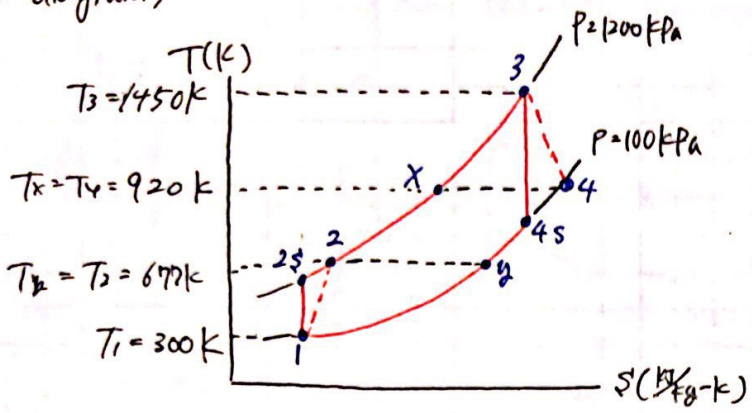
$h_y = 688.5\ \text{kJ/kg}$

thus

$$T_y = T_2$$

$T_y = 677K$

〈T-s diagram〉



(b) turbine

$$\dot{w}_{34} = h_3 - h_y = (1576 - 955.8)\,kJ/kg \cong 620.2\,kJ/kg$$

compressor

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

now

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

$$\therefore \dot{m} = \frac{10\times10^3\,kW}{(620.2 - 388.4)\,kJ/kg} \cong 43.14\,kg/s$$

$\dot{m} = 43.1\,kg/s$

(c) combustor

$$0 = \dot{Q}_{in} + \dot{m}(h_x - h_3)$$

$$\dot{Q}_{in} = (43.1\,kg/s)(1576 - 955.8)\,kJ/kg \cong 26.7\times10^3\,kW$$

$\dot{Q}_{in} = 26.7\times10^3\,kW$

(d)

$$\eta_{TH} = \frac{\dot{W}_{cycle}}{\dot{Q}_{in}}$$

$$= \frac{10\times10^3\,kW}{26.7\times10^3\,kW}$$

$$\cong 0.3744$$

$\eta_{TH} = 37.4\%$