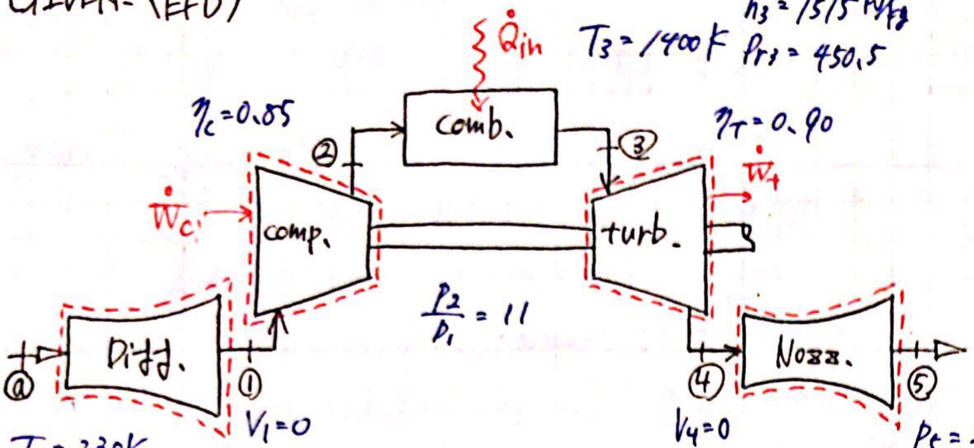
GIVEN: ⟨EFD⟩

$h_3 = 1515$ kJ/kg
$T_3 = 1400$ K, $P_{r3} = 450.5$



$P_{ra} = 0.5477$, $T_a = 230$ K
$P_a = 26$ kPa
$V_a = 220$ m/s
$\dot{m} = 25$ kg/s

FIND: (a) P, in kPa, T, in K for each state
(b) $\dot{Q}_{in}$, in kW
(c) V_5, in m/s

ASSUMP: open sys, SSSF, 1-DUF, $\Delta KE = \Delta PE = 0$ (* KE except Diff. inlet and Nozz. outlet), diff., nozz are isentropic, air standard sys, ideal gas, comb. only heat addition no pressure drop, Diff., Nozz, Comp., Turb. $\Rightarrow \dot{Q} = 0$, Diff. & Nozz. $\Rightarrow \dot{W} = 0$

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

SOLN:
(a)
⟨state 1⟩ for state a, we can find $h_a = 230.0$ kJ/kg
Since Diffuser $\dot{W} = 0$ & $\dot{Q} = 0$

$$0 = \cancel{\dot{Q}_{a1}}^{0} - \cancel{\dot{W}_{a1}}^{0} + \dot{m}(h_a - h_1) + \dot{m}\frac{V_a^2}{2}\cdot\frac{1}{1000}$$

$$\therefore h_1 = h_a + \frac{V_a^2}{2000} = 230.0 \text{ kJ/kg} + \frac{220^2}{2000} = 254.2 \text{ kJ/kg}$$

from this using interpolation

$$T_1 = (254.2 - 250.0)\text{ kJ/kg}\ \frac{(260 - 250)\text{ K}}{(260.0 - 250.0)\text{ kJ/kg}} + 250\text{ K} \cong 254.2\text{ K}$$

$\boxed{T_1 = 254\text{ K}}$

likewise

$$P_{r1} = (254.2 - 250.0)\text{ kJ/kg}\ \frac{0.8405 - 0.7329}{(260.0 - 250.0)\text{ kJ/kg}} + 0.7329$$

$$\cong 0.7781$$

since diff. is $\Delta s = 0$

$$p_1 = p_a \cdot \frac{p_{r1}}{p_{ra}} = 26\,kPa \cdot \frac{0.7781}{0.5477} \cong 36.9\,kPa$$ $\boxed{p_1 = 36.9\,kPa}$

<State 2> from CR

$$p_2 = 11 p_1 = 11(36.9\,kPa) \cong 406\,kPa$$ $\boxed{p_2 = 406\,kPa}$

and if comp. is $\Delta s = 0$

$$p_{r2} = p_{r1}\frac{p_2}{p_1} = (0.7781)\cdot 11 \cong 8.559$$

the corresponding h_{2s} is, from interpolation

$$h_{2s} = (8.559 - 8.411)\cdot\frac{(513.6 - 503.3)\,kJ/kg}{9.031 - 8.411} + 503.3\,kJ/kg$$
$$\cong 505.8\,kJ/kg$$

now with η_c

$$h_2 = \frac{1}{\eta_c}(h_{2s} - h_1) + h_1 = \frac{1}{0.85}(505.8 - 254.2)\,kJ/kg + 254.2\,kJ/kg$$
$$= 550.2\,kJ/kg$$

now the corresponding T_2 with interpolation is

$$T_2 = (550.2 - 544.6)\,kJ/kg \cdot \frac{550\,K - 540\,K}{(555.0 - 544.6)\,kJ/kg} + 540\,K$$
$$\cong 545.4\,K$$

$\boxed{T_2 = 545\,K}$

<State 3> since combustor has no p loss $p_3 = p_2$

$\boxed{P_3 = 406\,kPa}$

<State 4> since

$$\dot{w}_T + \dot{w}_c = 0$$
$$h_3 - h_4 + h_1 - h_2 = 0$$
$$h_4 = h_1 - h_2 + h_3 = (254.2 - 550.2 + 1515)\,kJ/kg$$
$$= 1219\,kJ/kg$$

interpolate to find T_4

$$T_4 = (1219 - 1208)\,kJ/kg \cdot \frac{(1160 - 1140)\,K}{(1231 - 1208)\,kJ/kg} + 1140\,K$$
$$\cong 1150\,K$$

$\boxed{T_4 = 1150\,K}$

from $\eta_T = 0.90$

$$h_{4s} = h_3 - \frac{1}{\eta_T}(h_3 - h_4) = 1515\,kJ/kg - \frac{1}{0.90}(1515 - 1219)\,kJ/kg$$
$$\cong 1186\,kJ/kg$$

then $h_{4s} \approx h|_{T=1120} \Rightarrow P_{r4} = (1186 - 1184)\,\text{kJ/kg} \dfrac{(193.1 - 179.7)}{(1208 - 1184)\,\text{kJ/kg}} + 179.7 \approx 180.8$

↳ for h_4 (actual)

therefore

$$P_4 = \frac{P_{r4}}{P_{r3}} P_3 = \frac{180.8}{450.5}(406\ \text{kPa}) \approx 162.9\ \text{kPa}$$

$$\boxed{P_4 = 163\ \text{kPa}}$$

<state 5> since Nozz. $\Delta s = 0$

$$P_{r5} = \frac{P_5}{P_4} P_{r4} = \frac{26\ \text{kPa}}{163\ \text{kPa}}(180.8) \approx 28.84$$

the corresponding temp. T_5 :

$$P_{r5} \approx P_r|_{T=700K} \Rightarrow h_5 = 713.3\ \text{kJ/kg}$$

$$\boxed{T_5 = 700\ K}$$

(b) For comb. <COE>

$$0 = \dot{Q}_{in} - \cancel{\dot{W}}^{\,0} + \dot{m}(h_2 - h_3)$$

$$\dot{Q}_{in} = \dot{m}(h_3 - h_2) = (25\ \text{kg/s})(1515 - 550.2)\ \text{kJ/kg}$$

$$= 24120\ \text{kW}$$

$$\boxed{\dot{Q}_{in} = 24.1 \times 10^3\ \text{kW}}$$

(c) For Nozz. <COE>

$$0 = \cancel{\dot{Q}_{45}}^{\,0} - \cancel{\dot{W}_{45}}^{\,0} + \dot{m}(h_4 - h_5) - \dot{m} \cdot \frac{V_5^2}{2} \cdot \frac{1}{1000}$$

$$V_5 = \sqrt{2000(h_4 - h_5)}$$

$$= \sqrt{2000(1219\ \text{kJ/kg} - 713.3\ \text{kJ/kg})}$$

$$\approx \boxed{1005\ \text{m/s}}$$