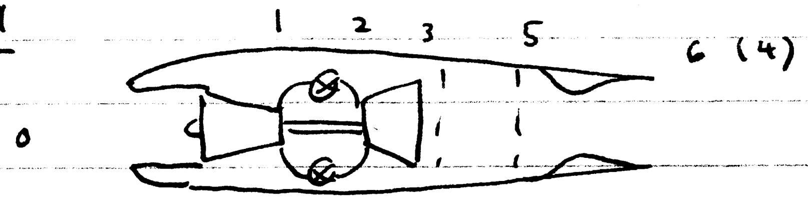
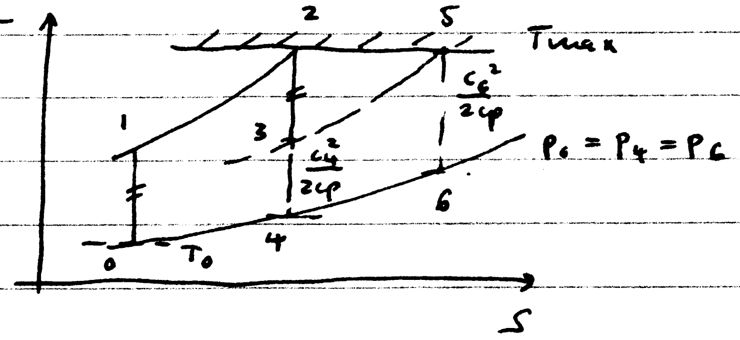
T19



$T_1/T_0 = \tau_s = 2$

$T_{max}/T_0 = \tau_m = 10$

a) [and d)]



assume: - ideal gas
const. spec. heats
- neglect fuel in
- ΔKE across turbomachines neglected

b) $\eta_{th} = \dfrac{w}{q_A} = 1 - \dfrac{q_R}{q_A} = 1 - \dfrac{T_0}{T_1}$, $\underline{\eta_{th}} = 1 - \dfrac{1}{\tau_s} = \underline{0.5}$

same TR $\left.\begin{matrix} 0 \to 1 \\ 4 \to 2 \end{matrix}\right\}$

c) $w = q_A - q_R = c_p(T_2 - T_1) - c_p(T_4 - T_0)$, $w = c_p T_0 \left[\tau_m - \tau_s - \dfrac{T_4}{T_0} + 1\right]$

$\dfrac{T_4}{T_0} = \dfrac{T_4}{T_2} \cdot \dfrac{T_2}{T_0} = \dfrac{T_0}{T_1} \cdot \dfrac{T_2}{T_0} = \dfrac{\tau_m}{\tau_s} = 5$; $\underline{w = 4 c_p T_0}$

d) see above T-s diagram

e) shaft power balance : $T_1 - T_0 = T_2 - T_3$; $\dfrac{T_3}{T_0} = \tau_m - \tau_s + 1 = 9$

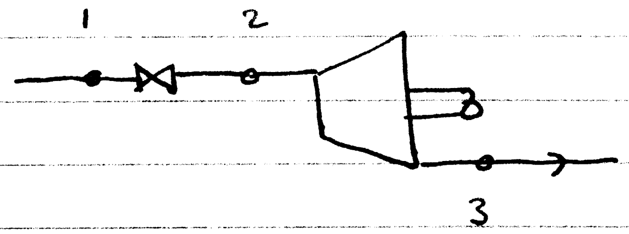
$\underline{T_3 = 9 T_0}$

f) $p_3 = p_5$ and $p_4 = p_6$ so $\dfrac{T_3}{T_4} = \dfrac{T_5}{T_6}$; $\dfrac{T_3}{T_0} \cdot \dfrac{T_0}{T_4} = \tau_m \cdot \dfrac{T_0}{T_6}$

$\dfrac{T_6}{T_0} = \tau_m \cdot \dfrac{T_4}{T_0} \cdot \dfrac{T_0}{T_3} = \dfrac{50}{9}$ $\underline{T_6 = \dfrac{50}{9} \cdot T_0}$

g) $\eta_{th}^{(a)} = 1 - \dfrac{q_R^{(a)}}{q_A^{(a)}} = 1 - \dfrac{T_6 - T_0}{T_2 - T_1 + T_5 - T_3} = 1 - \dfrac{T_6/T_0 - 1}{\tau_m - \tau_s + \tau_m - T_3/T_0}$

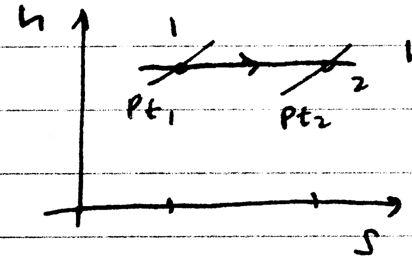
$\eta_{th}^{(a)} = 1 - \dfrac{50/9 - 9/9}{20 - 2 - 9} = 1 - \dfrac{41}{81}$; $\underline{\eta_{th}^{(a)} = \dfrac{40}{81} = 0.494}$



$P_{t_1} = 10\,\text{bar}$, $T_{t_1} = 600\,C$

$P_{t_3} = 1\,\text{bar}$ adiabatic components, ideal turbine

a)



1st law: $h_t = \text{const}$; $dh_t = 0$ (no work, no heat x-fer)

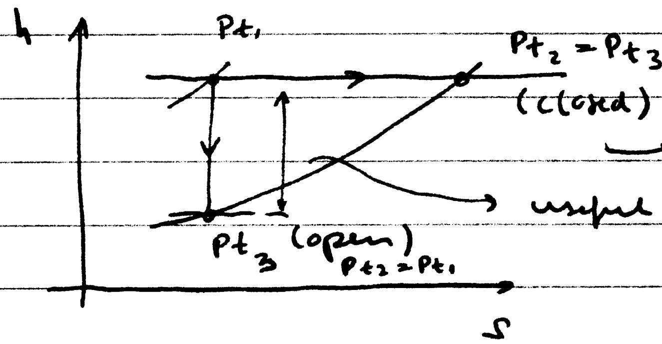
Gibbs: $T_t ds = \cancel{dh_t} - \frac{1}{\rho_t} dp_t$

$\frac{ds}{R} = -\frac{dp_t}{p_t}$ since $T_t ds = dq > 0$

$\frac{dp_t}{p_t} < 0$: p_t decreases

entropy generated during expansion (free!) in throttle

b)



c) 1st law: $w_s = h_{t_1} - h_{t_3} = c_p T_{t_1} \left[1 - \left(\frac{P_{t_3}}{P_{t_1}} \right)^{\frac{\gamma-1}{\gamma}} \right]$

isentropic expansion $\frac{T_{t_3}}{T_{t_1}} = \left(\frac{P_{t_3}}{P_{t_1}} \right)^{\frac{\gamma-1}{\gamma}}$ $\underline{w_s = 422.7\ \text{kJ/kg}}$

d) $P_{t_2} = P_{t_3}$ throttle closed

Gibbs: $T_t ds = \cancel{dh_t}^{\,0\ \text{(1st law)}} - v_t dp_t$ $\quad ds = -R \frac{dp_t}{p_t} \quad \Big| \int_1^2$

$\Delta s_{12} = -R \ln\left(\frac{P_{t_2}}{P_{t_1}} \right) = R \ln \left(\frac{P_{t_1}}{P_{t_3}} \right)$ $\quad \underline{\Delta s_{12} = 660.8\ \text{J/kg-K}}$

since no heat interaction with surr. $\Delta s_{total} = \Delta s_{12} = \Delta s_{gen}$

$\to$ throttle generates entropy (free expansion)