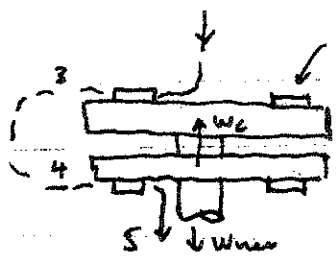
T5



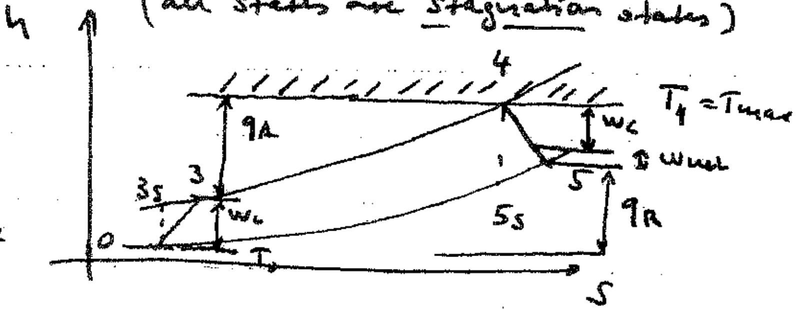
16. Unified Sp 09

ZS

MIT μ-engine cycle

(all states are stagnation states)

a)



$\pi = 3$, $\tau_{max} = \frac{T_4}{T_0} = 5$, $\eta_T = 0.7$

Concepts: 1st and 2nd law, definition of thermal eff, adiab. eff.

b) $\eta_{th} = \frac{w_{net}}{q_A} = 1 - \frac{q_R}{q_A} = 1 - \frac{T_5 - T_0}{T_4 - T_3}$ define $\tau_s = \pi^{\frac{\gamma-1}{\gamma}}$

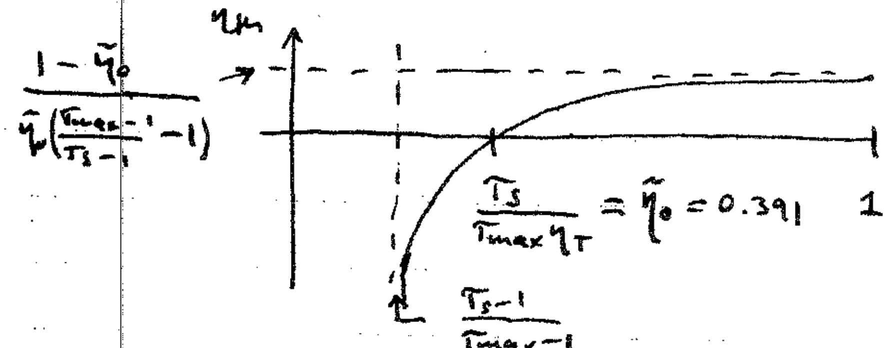
Using def. of η_T and isentropic relations: $T_5 = T_4\left(1 - \eta_T\left(1 - \frac{1}{\tau_s}\right)\right)$

Similarly for compressor: $T_3 = T_0\left(1 + \frac{1}{\eta_c}(\tau_s - 1)\right)$

Substitute in above: $\eta_{th} = 1 - \frac{T_4/T_0\left(1 - \eta_T\left(1 - \frac{1}{\tau_s}\right)\right) - 1}{T_4/T_0 - \left(1 + 1/\eta_c(\tau_s - 1)\right)}$

Using $\tau_{max} = T_4/T_0$ find with $\tilde{\eta}_0 = \tau_s/(\tau_{max}\eta_T)$

$$\eta_{th} = \frac{\eta_c\left[\tau_{max}\eta_T(1 - \tau_s^{-1})\right] - (\tau_s - 1)}{\eta_c\left[\tau_{max} - 1\right] - (\tau_s - 1)} = \frac{\eta_c/\tilde{\eta}_0 - 1}{\eta_c\frac{\tau_{max} - 1}{\tau_s - 1} - 1}$$



c) If $\eta_{th} > 0$ will produce net work so

$w_{net} > 0$ for $\eta_c > \frac{\tau_s}{\tau_{max}\eta_T}$

$\eta_c > 0.391$

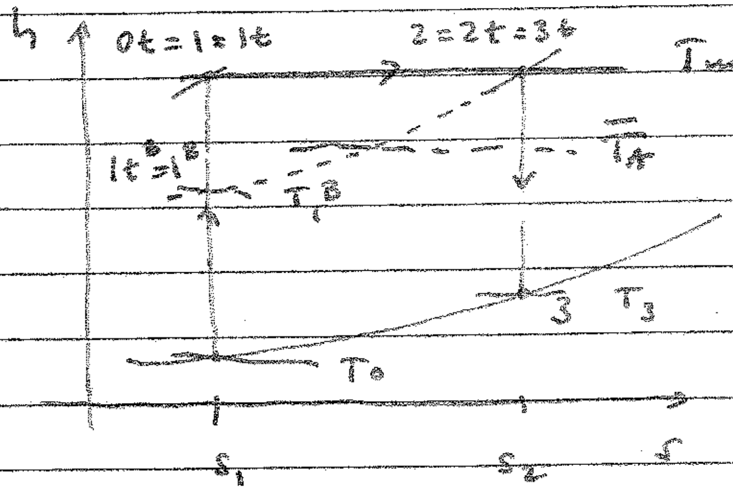
d) $P = \dot{m} w_{net}$, $w_{net} = c_p T_4 \eta_T(1 - \tau_s^{-1}) - \frac{c_p T_0}{\eta_c}(\tau_s - 1)$, for $\eta_c = 0.55 \rightarrow w_{net} = 82 \frac{kJ}{kg}$

$\dot{m} = \rho_{inlet} A_{inlet} u_{inlet}$; $P_{inlet} = P_0\left(1 + \frac{\gamma-1}{2} M_{in}^2\right)^{\frac{-\gamma}{\gamma-1}}$, $T_{inlet} = T_0\left(1 + \frac{\gamma-1}{2} M_{in}^2\right)^{-1}$

$\rho_{inlet} = \frac{P_{inlet}}{R\,T_{inlet}}$, $u_{inlet} = M_{inlet}\sqrt{\gamma R T_{inlet}}$, $\longrightarrow$ find $P = 32.9$ W

T4 16. Unified Sp 09 ZS

a)



know:

$T_1/T_0 = 10$

$T_2/T_3 = 2.5$

$\frac{\Delta s_{12}}{c_p} = \ln 4$

b) $\eta_{th} = \frac{w_{net}}{q_A} = 1 + \frac{q_R}{q_A}$; (note $q_R < 0$)

$1 \to 2$: $T ds = dq \quad \int_1^2$

$q_A = T_1 \Delta s_{12}$

$3 \to 0$: $T ds = dq = dh \quad \int_3^0$

$q_R = c_p (T_0 - T_3) < 0$

$$\eta_{th} = 1 - \frac{T_3 - T_0}{\Delta s_{12}/c_p \, T_1}$$

$$\eta_{th} = 1 - \frac{T_3/T_1 - T_0/T_1}{\Delta s_{12}/c_p} \; ; \; \eta_{th} = 1 - \frac{1/2.5 - 1/10}{\ln 4} \quad \underline{\eta_{th} = 0.78}$$

c) heat added at const pressure, same T_{max}, T_2/T_3

$$\eta_{th}^B = 1 - \frac{T_0}{T_1^B} \; ; \quad \text{same PR} \to \text{same TR} : \frac{T_{1B}}{T_0} = \frac{T_2}{T_3}$$

$$\eta_{th}^B = 1 - \frac{T_3}{T_2} \; ; \quad \underline{\eta_{th}^B = 0.6}$$

$\eta_{th}^B < \eta_{th}$ because heat added at average temperature lower than max. cycle temp (const. in a))

$\bar{T}_A < T_{max}$