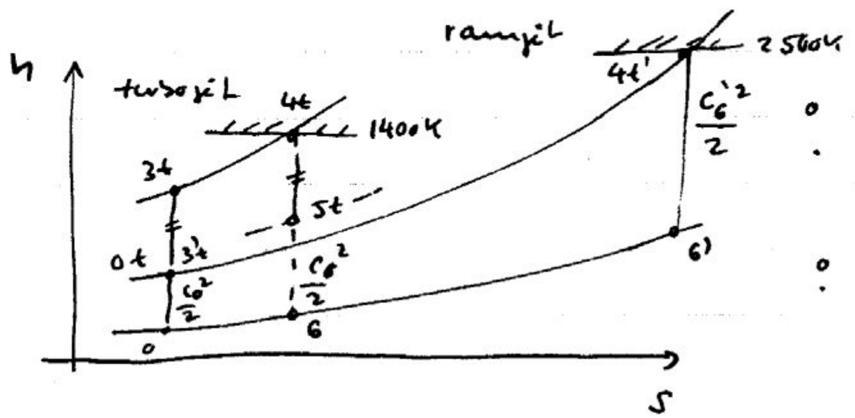
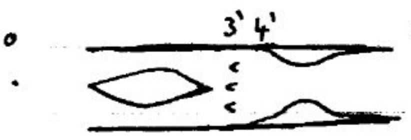
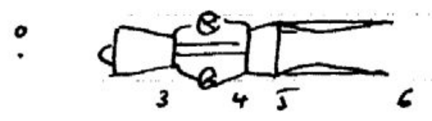
T7

16. Unified Sp 08

a)







b) **turbojet:**

$q_A = f \cdot \Delta h_f = c_p (T_{4t} - T_{3t})$

$T_{0t} = T_0 \left(1 + \frac{\gamma-1}{2} M_0^2\right) = 297.25\,K$

$T_{3t} = T_{0t} \cdot \Pi^{\frac{\gamma-1}{\gamma}} = 604.59\,K$

find $\underline{f = 0.017755}$

$\eta_{th} = 1 - \frac{T_0}{T_{3t}} = \frac{c_6^2 - c_0^2}{2 q_A}$, $c_0 = \sqrt{\gamma R T_0} \cdot M_0 = 40.5\,m/s$

find $\underline{c_6 = 1114.2\ m/s}$

$\underline{\underline{SFC = \frac{\dot m_f}{F} = \frac{f}{c_6 - c_0} = 0.0935\ \frac{kg}{N\text{-}hr}}}$

ramjet:

$q_A' = f' \Delta h_f = c_p (T_{4t}' - T_{0t})$

find $f' = 0.04917$

$\eta_{th}' = 1 - \frac{T_0}{T_{0t}} = \frac{\frac{\gamma-1}{2} M_0^2}{1 + \frac{\gamma-1}{2} M_0^2} = \frac{c_6'^2 - c_0^2}{2 q_A'}$

find $\underline{c_6' = 1248.5\ m/s}$

$SFC' = \frac{\dot m_f'}{F'} = \frac{f'}{c_6' - c_0}$

$\underline{\underline{SFC' = 0.2164\ kg/N\text{-}hr}}$

c) $\eta_{th} = 0.66$, $\eta_{prop} = \frac{2}{1 + \frac{c_6}{c_0}} = 0.56$

$\eta_0 = \eta_{th} \cdot \eta_{prop} = 0.369$

$\eta_{th}' = 0.31$, $\eta_{prop}' = \frac{2}{1 + c_6'/c_0} = 0.51$

$\eta_0' = \eta_{th}' \cdot \eta_{prop}' = 0.158$

Turbojet yields better performance because thermal eff about twice of that of ramjet while prop. efficiency is about the same. This is governed by the much higher cycle pressure ratio of the TJ

d) same analysis but $M_0 = 3$

find $\underline{SFC = 0.0934}$

$\eta_{th} = 0.824$, $\eta_{prop} = 0.895$

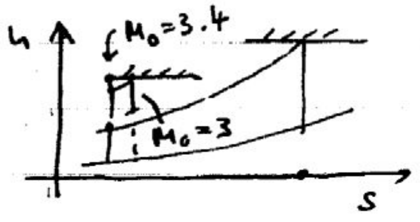
for $T_{3t} \to T_{max}$: $\eta_{prop} \to 1$

Turbojet still better in performance but ramjet SFC improved by 20%. (TJ stays ~ the same)

$M_0 = 3$:

$\underline{SFC' = 0.165}$

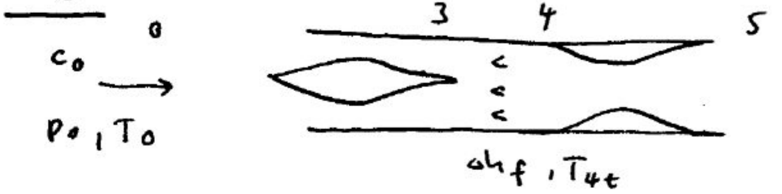
$\eta_{th}' = 0.643$, $\eta_{prop}' = 0.648$



Note: turbojet will not operate @ $M_0 = 3.4$ can't add heat!

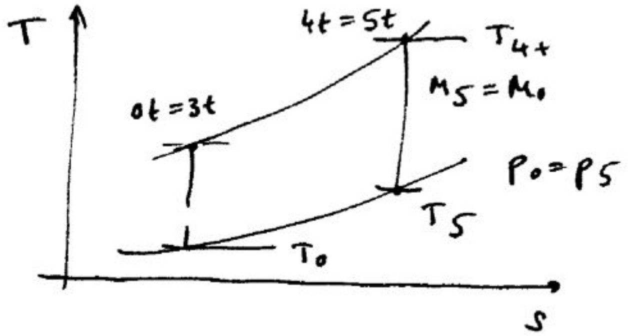
T8

16. Unified Sp08



$p_5 = p_0$

a)



know: $\begin{cases} T_{t4} = 2903\text{ K} \\ P_p = c_0 \dot{m} (c_5 - c_0) \\ \quad = 7.5\text{ MW} \\ T_0 = 222\text{ K}, \; p_0 = 0.2\text{ bar} \\ \Delta h_f = 43\text{ MJ/kg} \end{cases}$

b) $T_{t3} = T_{t0} = T_0 \left(1 + \frac{\gamma-1}{2} M_0^2\right)$, $M_0 = \frac{c_0}{\sqrt{\gamma R T_0}}$, $M_0 = 3.06$

$\underline{T_{t3} = 637.7\text{ K}}$, $P_{t3} = p_0 \left(1 + \frac{\gamma-1}{2} M_0^2\right)^{\gamma/\gamma-1}$, $\underline{P_{t3} = 8.036\text{ bar}}$

c) $M_5 = M_0 \rightarrow T_5 = T_{t4} \left(1 + \frac{\gamma-1}{2} M_0^2\right)^{-1}$, $c_5 = M_0 \sqrt{\gamma R T_5}$, $\underline{c_5 = 1810.5\text{ m/s}}$

d) $\dot{m} = \frac{P_p}{c_0 (c_5 - c_0)}$; $\underline{\dot{m} = 9.153\text{ kg/s}}$

e) $w_{mech} = \frac{c_5^2}{2} - \frac{c_0^2}{2}$; $\underline{w_{mech} = 1.22\text{ MJ/kg}}$

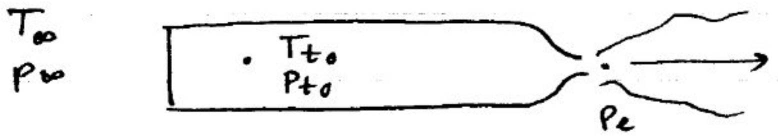
f) $q_A = f \cdot \Delta h_f = h_{t4} - h_{t3}$, $\underline{f = 0.0436}$ $\underline{\dot{m}_f} = \dot{m} \cdot f$ $\underline{= 0.399\text{ kg/s}}$

g) $\eta_{prop} = \frac{2}{1 + c_5/c_0}$ $\underline{\eta_{prop} = 0.671}$

h) $TSFC = \frac{\dot{m}_f}{F} = \frac{f}{c_5 - c_0}$

$\underline{TSFC = 0.175\text{ kg/N-h}}$

T9



a) assume: quasi-steady flow, adiabatic

1st law : $T_{te} = T_{t0}$ (no work no heat transfer)

$T_{t0} = T_0$ (thermal equilibrium before bottle dropped)

Sonic flow : $M_e = 1.0$

find $T_e = T_0 \left(1 + \frac{\gamma-1}{2}\right)^{-1} \rightarrow \underline{T_e = 240K}$

isentropic flow:

$p_{te} = p_e \left(1 + \frac{\gamma-1}{2}\right)^{\frac{\gamma}{\gamma-1}} = p_{t0} \rightarrow \underline{p_e = 79.2 \text{ bar} \gg p_\infty} \; !$

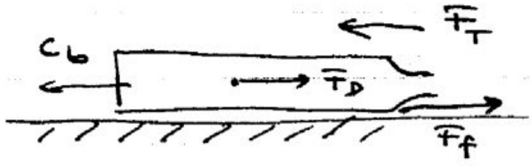
Note: streamlines bulge outward, have expansion fan

streamlines are not parallel

b) $\dot m = \rho_e A_e c_e$, $c_e = \sqrt{\gamma R T_e}$, $\dot m = \sqrt{\gamma R}\, A_e \frac{p_e}{R\sqrt{T_e}} = \sqrt{\frac{\gamma}{R}}\, A_e \frac{p_e}{\sqrt{T_e}}$

$\underline{\dot m = 2.8 \text{ kg/s}}$, $c_e = 310.5 \text{ m/s}$

c)



steady motion : $\Sigma F = 0$

$F_T = F_f + F_D$

$$\dot m (c_e) + A_e (p_e - p_\infty) = \frac{1}{2} \rho_\infty A_b c_b^2 c_D + m_b g c_f$$

$$c_b = \sqrt{\frac{\dot m c_e + A_e (p_e - p_\infty) - m_b g c_f}{\frac{1}{2} \rho_\infty A_b c_D}}$$

find $\underline{c_b = 212.5 \text{ m/s}}$!

or $M_b = \frac{c_b}{\sqrt{\gamma R T_\infty}} = 0.62$