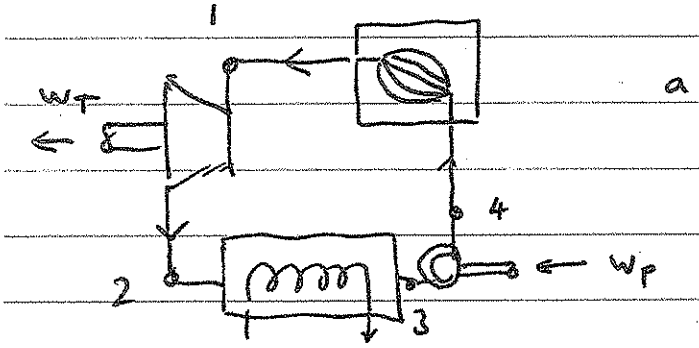
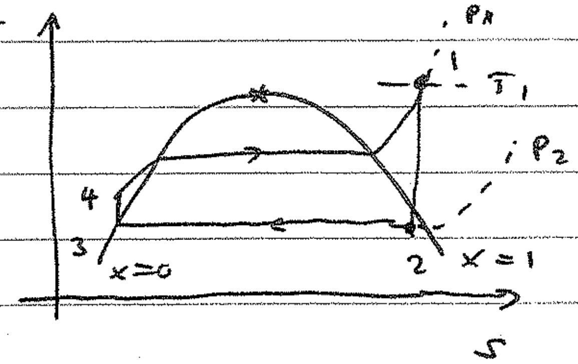
T4 16. Unified Sp08



a)



b) $P_1 = 20\,\text{bar}$, $T_1 = 360°C$ $\longrightarrow$ $\underline{h_1 = 3159\ \text{kJ/kg}}$, $s_1 = 6.99\ \text{kJ/kg-K}$

$P_2 = P_3 = 0.08\ \text{bar}$ $\longrightarrow$ $s_2 = s_1$; so $x_2 = \dfrac{s_2 - s_f}{s_{fg}} = 0.837$

find $h_2 = h_g x_2 + (1-x_2) h_f$ $\longrightarrow$ $\underline{h_2 = 2185\ \text{kJ/kg}}$

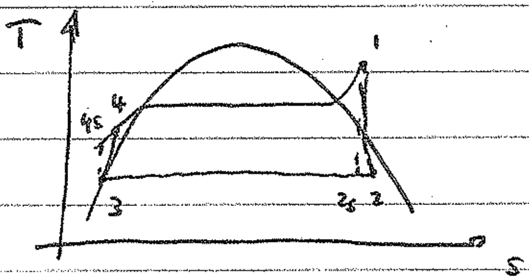
state 3: $\underline{h_3} = h_f(P_3) = \underline{173.38\ \text{kJ/kg}}$, $V_3 = V_f(P_3) = 0.001008\ \text{m}^3/\text{kg}$

state 4: $W_p = h_4 - h_3 = V_3(P_4 - P_3)$ $\longrightarrow$ $\underline{h_4 = 175.39\ \text{kJ/kg}}$

$W_{net} = q_A - q_R$, $\eta_{th} = 1 - \dfrac{q_R}{q_A}$, $q_A = h_1 - h_4$, $q_R = h_2 - h_3$

$\underline{W_{net} = 972\ \text{kJ/kg}}$, $\underline{\eta_{th} = 0.326}$

c)



$\eta_P = \dfrac{h_{4s} - h_3}{h_4 - h_3} = 0.8$, $\eta_T = \dfrac{h_1 - h_2}{h_1 - h_{2s}} = 0.8$

$W_{net}^{act.} = \underbrace{(h_1 - h_2)}_{W_T^{actual}} - \underbrace{(h_4 - h_3)}_{W_P^{actual}}$

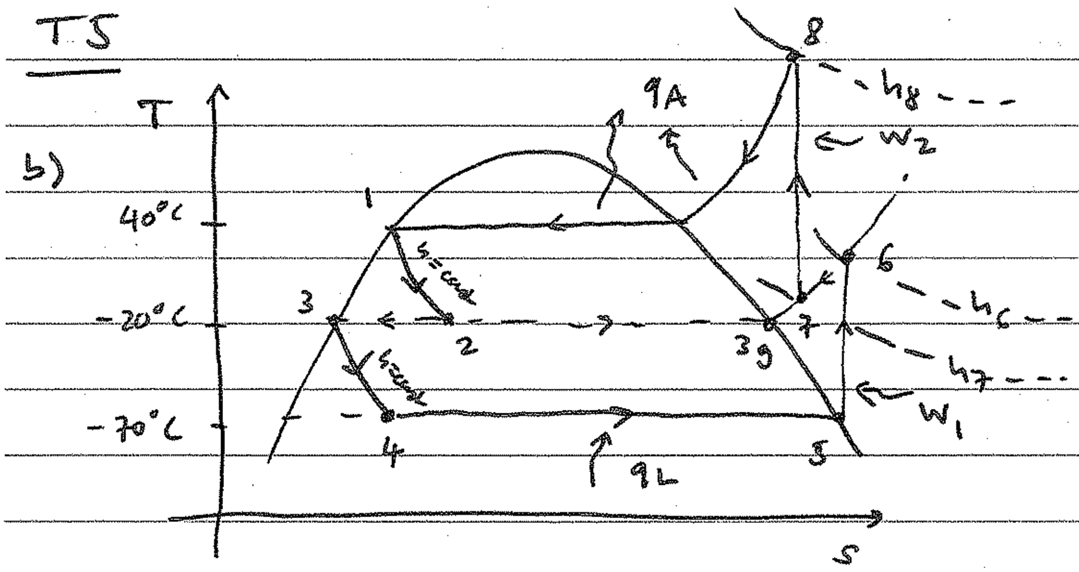
$$\left.\begin{array}{l} h_4 - h_3 = \dfrac{1}{\eta_P}(h_{4s} - h_3) = 2.51\ \text{kJ/kg} \\ h_1 - h_2 = \eta_T(h_1 - h_{2s}) = 779.2\ \text{kJ/kg} \end{array}\right\} \quad \begin{array}{l} \underline{W_{net}^{actual} = 776.69\ \text{kJ/kg}} \\ \underline{\eta_{th}^{actual} = 0.26} \end{array}$$

Percentage reduction compared to ideal case

$\underline{\dfrac{W_{net} - W_{net}^{act}}{W_{net}} = 0.2}$ $\qquad$ $\underline{\dfrac{\eta_{th} - \eta_{th}^{act}}{\eta_{th}} = 0.2}$

TS 16. Unified Sp 08

b)



Note: slope of isenthalps in 2-phase region

c) $q_L = h_5 - h_4$ $\quad h_5 = h_g(-70°C) = 155.64$ kJ/kg

1st law CV throttle: $h_3 = h_4$ (no work no heat x-fer)

Note: temperature drops! → expansion

$h_3 = h_f(-20°C) = 17.82$ kJ/kg $\qquad$ find $\underline{q_L = 137.82 \text{ kJ/kg}}$

d) $w_1 = h_6 - h_5$; $h_6 = ?$ $\qquad s_6 = s_5 = s_g(-70°C) = 0.7749$ kJ/kg K

$P_6 = P_s(-20°C) = 150.9$ kPa

$\longrightarrow h_6 = 195.373$ kJ/kg

find $\underline{w_1 = 39.73 \text{ kJ/kg}}$ supplied to compressor

e) $w_2 = h_8 - h_7$; $h_{3g} = h_g(-20°C) = 178.74$ kJ/kg

find x_{flash}: throttle $h_1 = h_2 = h_f(40°C) = 74.59$ kJ/kg

$h_2 = h_g(-20°C)\, x_2 + (1-x_2)\, h_f(-20°C)$

$\longrightarrow x_2 = \dfrac{h_2 - h_f(-20°C)}{h_{fg}(-20°C)} = \underline{0.3528}$, 1st law mixing chamber:

$h_7 = x_2 \underbrace{h_{3g}}_{178.74} + (1-x_2)\, h_6 = 189.5 \frac{\text{kJ}}{\text{kg}}$

$P_7 = P_6 = P_s(-20°C) = 150.9$ kPa

$\longrightarrow s_7 = 0.7536$ kJ/kg ; $s_8 = s_7$ and $P_8 = P_s(40°C) = 960.7$ kPa

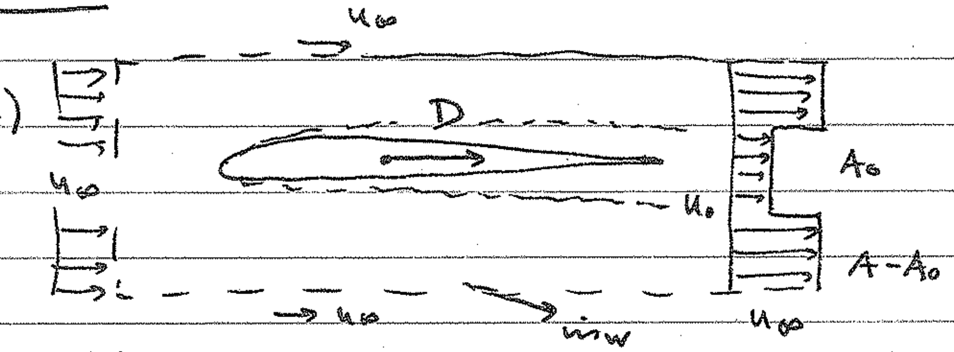
$\longrightarrow h_8 = 226.45$ kJ/kg $\qquad$ find $\underline{w_2 = 36.94 \text{ kJ/kg}}$

f) $COP = \dfrac{(1-x_2)\, q_L}{(1-x_2)\, w_1 + w_2}$; find $\underline{COP = 1.424}$

Note: only liquid flows thru evaporator and compressor 1

T6 16. Unified Sp08

a)



Concepts:
- integral mom. theorem
- propulsive efficiency

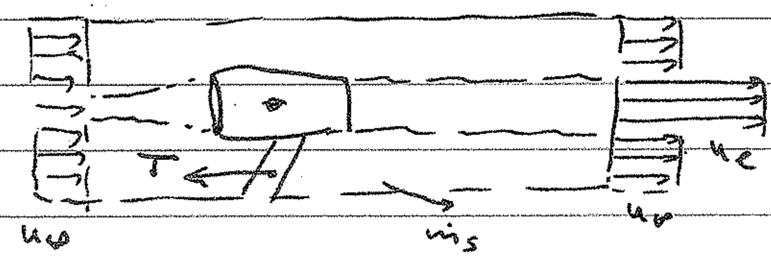
Note: for rectangular CV, wake flow spilled

$$-\rho A u_\infty^2 + \rho A_0 u_0^2 + \rho (A-A_0) u_\infty^2 + \dot m_w u_\infty = -D \quad \text{(force on fluid!)}$$

$$\dot m_w = \rho A_0 (u_\infty - u_0)$$

find $\underline{D = \rho A_0 u_0 (u_\infty - u_0)}$

b)



similar CV analysis (see lecture notes-blackboard)

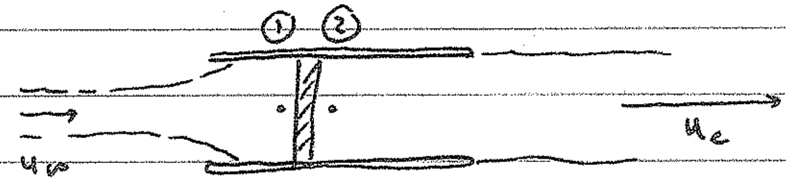
$\underline{T = \rho A_e u_e (u_e - u_\infty)}$

(Note: spilled mass flow due to streamline contraction upstream)

c) steady level flight $\rightarrow T = D$

find $$\underline{A_e / A_0 = \frac{u_0 (u_\infty - u_0)}{u_e (u_e - u_\infty)}}$$

d)



Bernoulli upstream and downstream of fan

p_∞ $\quad \Delta p_{t_{fan}} = p_{t_2} - p_{t_1}$ $\quad p_\infty$

$$\underline{\Delta p_{t_{fan}} = \frac{1}{2}\rho\left(u_e^2 - u_\infty^2\right)}$$

e) fan power input: 1st law $\dot W_{fan} = \dot m (h_{t_2} - h_{t_1})$

$\dot m = \rho u_e A_e$ $\quad$ Gibbs: $T_t \underset{0}{ds} = dh_t - \frac{1}{\rho_t} dp_t \ \wedge\ \rho_t \approx \rho$

$$h_{t_2} - h_{t_1} = \frac{1}{\rho}(p_{t_2} - p_{t_1}) \qquad \underline{\dot W_{fan} = \frac{1}{2}\rho A_e u_e \left(u_e^2 - u_\infty^2\right)}$$

f) required power to propel vehicle: $\dot W_{prop} = u_\infty \cdot T$

$$\underline{\dot W_{prop} = u_\infty \cdot \rho A_e u_e (u_e - u_\infty)}$$

Note: $$\eta_{prop} = \frac{\dot W_{prop}}{\dot W_{fan}} = \frac{2}{1 + \frac{u_e}{u_\infty}} \quad \text{q.e.d.}$$