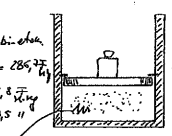
# Soluzione del compito di Fisica Tecnica del 6 luglio 2015

**ATTENZIONE: la presente soluzione è <u>puramente indicativa</u> e non si escludono errori e/o omissioni.**

## Problema 1




1. $U_2 - U_1 = L_{el}$ — Ad.

$L_{el} = \int_0^t W\,dt' = Wt$

(1.P) $\rightarrow mc_v(T_2 - T_1) = Wt$

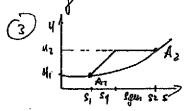
$T_2 = T_1 + \frac{Wt}{mc_v} = 20 + \frac{10 \times 100}{0,002 \times 716,8} = 716,8\,K = 990,73\,K$

$p_2 = \frac{mR^*T_2}{V_2} = \frac{0,002 \times 286,7 \times 990,73}{0,294 \cdot 10^{-3}} = 6,8 \cdot 10^5\,Pa$

8. $S_2 - S_1 = m\left[c_v \ln\frac{T_2}{T_1} + R \ln\frac{V_2}{V_1}\right] = 0,002 \times 716,8 \ln\frac{990,73}{293} = 1,746\,\frac{J}{K}$

$S_{gen} = S_2 - S_1 - S^{est}_q$ positività? $>0$ il processo $A_1 \rightarrow A_2$ è irreversibile

3.




4. $A_2 \rightarrow A_3$ $\quad U_3 - U_2 = Q_{23} - L_{23}$ ; $L_{23} = \int_2^3 F_p\,dx = F_p(x_3 - x_2) = p(V_3 - V_2)$

(1.P) $mc_v(T_3 - T_2) = -p_3(V_3 - V_2)$ $\quad = \frac{p_2}{V_2}(V_3 - V_2) = p_3(V_3 - V_2)$

$mc_v T_3 + p_3 V_3 = mc_v T_2 + p_3 V_2$

$mc_v T_3 + mR^* T_3 = mc_v T_2 + p_3 V_2 \rightarrow m(c_v + R^*)T_3 = mc_v T_2 + p_3 V_2$

$T_3 = \frac{c_v}{c_p} T_2 + \frac{p_3 V_2}{mc_p} = \frac{990,73}{1,4} + \frac{1,8 \cdot 10^5 \times 984 \cdot 10^{-3}}{0,002 \times 1003,5} = 783\,K = 509,85\,C$

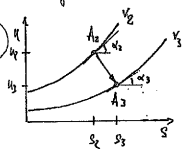
$V_3 = \frac{mR^*T_3}{p_3} = \frac{0,002 \times 286,7 \times 783}{1,8 \cdot 10^5} = 2,5 \cdot 10^{-3}\,m^3$

$L_{23} = 1,8 \cdot 10^5 (2,5 - 0,84) \cdot 10^{-3} = 298\,J$

5. $S_3 - S_2 = S^{est}_{q\,23} + S_{gen\,23}$ — Ad.

$\rightarrow S_{gen\,23} = S_3 - S_2 = m\left[c_p \ln\frac{T_3}{T_2} - R^* \ln\frac{p_3}{p_2}\right] = 0,287\,\frac{J}{K} > 0$ (IRREV.)

6.

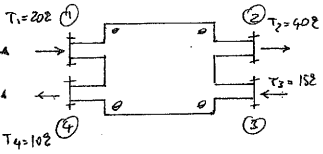



$U_2 > U_3 > U_1$

$S_3 > S_2 > S_1$

## Problema 2

1.




$\frac{dm^{ae}}{dt} = \dot m_1 - \dot m_2 = 0 \rightarrow \dot m_2 = \dot m_1$

$\frac{dm^{ac}}{dt} = \dot m_3 - \dot m_4 = 0 \rightarrow \dot m_4 = \dot m_3$

$\frac{dE}{dt} = \dot m_1 h_1 - \dot m_2 h_2 + \dot m_3 h_3 - \dot m_4 h_4 - \dot Q_0 - \dot L' = 0$

$\dot m_3 = \frac{h_2 - h_1}{h_3 - h_4}\dot m_2$ (1.P) $\dot m_2 = \frac{q_p(T_2 - T_1)}{c(T_3 - T_4) + s(p_3 - p_4)}\dot m_2$ (1.2)

$\dot m_2 = \rho_2 \dot V_2 = 1,129 \times \frac{3200}{3600} = 1\,kg/s$

$\rho_2 = \frac{1}{v_2} = \frac{p_2}{R^* T_2} = \frac{101325 \times 29}{8314,5 \times 313} = 1,129\,kg/m^3$

$c_p = \frac{7}{2} R^* = 1003,5\,\frac{J}{kg\,K}$

$\dot m_3 = \frac{1003,5(40 - 20)}{4200(15 - 10)} \times 1 = 0,956\,kg/s$

$\dot V_3 = \dot m_3 v_3 = 0,956 \times 0,001 \times 3600 = 3,44\,\frac{m^3}{h}$

2. $\frac{dS}{dt} = \dot m_1 s_1 - \dot m_2 s_2 + \dot m_3 s_3 - \dot m_4 s_4 - \dot S^{est}_{q_0} + \dot S_{gen} = 0$ (1.P, 1.S)

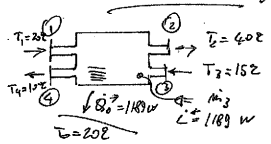
$\dot S_{gen} = -\dot m_3(s_3 - s_4) + \dot m_1(s_2 - s_1) = -\dot m_3 c \ln\frac{T_3}{T_4} + \dot m_1 q\left(\ln\frac{T_2}{T_1} - \frac{R^*}{q_p}\ln\frac{p_2}{p_1}\right) =$ (1.1, 1.P)

$= -0,956 \times 4200 \ln\frac{288,15}{283,15} + 1 \times 1003,5 \ln\frac{313,15}{293,15} = 4,055\,\frac{W}{K} > 0$

70,284 — 66,229 — NON SI PUÒ FERMARE!

3. $\frac{dE}{dt} = \dot m_1 h_1 - \dot m_2 h_2 + \dot m_3 h_3 - \dot m_4 h_4 - \dot Q_0 + \dot L = 0$ (1.E)

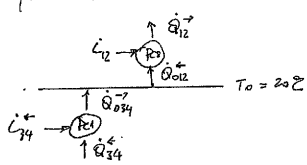
$\frac{dS}{dt} = \dot m_1 s_1 - \dot m_2 s_2 + \dot m_3 s_3 - \dot m_4 s_4 - \dot S^{est}_{q_0} + \dot S_{gen} = 0$ (1.S)




$\dot L = \dot Q_0 = 1189\,W$

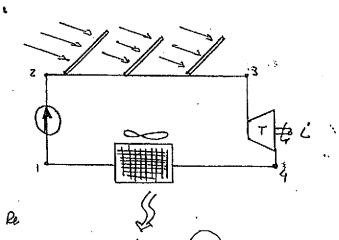
$\dot S_{gen} = \dot m_3(s_3 - s_4) - \dot m_1(s_2 - s_1) = 4,055\,\frac{W}{K} \rightarrow \dot Q_0 = T_0 \dot S_{gen} = 1189\,W$ (q. tot)

4.




$\dot Q_{034} - \dot Q_{012} = (\dot Q_{34} + \dot L_{34}) - (\dot Q_{12} - \dot L_{12}) = \dot L_{34} + \dot L_{12}$ V

## Problema 3

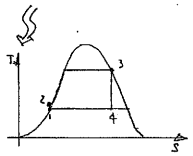



1. $\frac{dm}{dt} = \dot m_3 - \dot m_4 = 0$

$\frac{dE^T}{dt} = \dot m_3 h_3 - \dot m_4 h_4 - \dot L^T = 0$ (1.S)

$\frac{dS^T}{dt} = \dot m_3 s_3 - \dot m_4 s_4 - \dot S^{est}_q + \dot S_{gen} = 0$ — Ad.

$L^T_{34} = \dot m_3(h_3 - h_4)$ ; $s_3 = s_4$ ; $\dot m_3 = \frac{\dot L^T_{34}}{h_3 - h_4}$




$h_3 = h_{v1}(T_3) = 276\,kJ/kg$ , $s_3 = s_{v1}(T_3) = 0,8973\,kJ/kg\cdot K$

$s_4 = s_{l1}(p_1) + x_4(s_{v1} - s_{l1})_{p=p_1} = s_3 \rightarrow x_4 = \frac{s_3 - s_{l1}(p_1)}{(s_{v1} - s_{l1})_{p=p_1}}$

$x_4 = \frac{0,8973 - 0,3}{0,9097 - 0,3} = 0,9797$

$h_4 = h_{l1}(p_1) + x_4[h_{v1} - h_{l1}]_{p=p_1} = 79,48 + 0,9797(259,19 - 79,48) = 255,54\,\frac{kJ}{kg}$ (179,71)

$\dot m_3 = \frac{10\,kW}{(276 - 255,54)\,\frac{kJ}{kg}} = 0,489\,kg/s$

2. $\frac{dE^c}{dt} = \dot m_2 h_1 - \dot m_3 h_3 + \dot Q_c = 0 \rightarrow \dot Q^c = \dot m_3(h_3 - h_2)$ ($h_1 = h_2$)

$\dot Q_c = 0,489 \times (276 - 79,48) = 96,05\,kW$ (196,52)

$A = \frac{\dot Q_c}{q} = \frac{96,05\,kW}{0,750\,kW/m^2} = 128\,m^2$

3. $\eta = \frac{\dot L}{\dot Q_c} = \frac{10}{96,05} = 10,4\,\%$

4. $\dot L^{pp} = \dot m(h_c - h_1) = \dot m s(p_2 - p_1) = 0,489 \times 0,000\,82(1,68 - 0,6) \cdot 10^6 = 430\,W$ (1.I, Rev)

$\dot L_u = \dot L^T - \dot L^{pp} = 10 - 0,43 = 9,57$

$\eta' = \frac{9,57}{96,05} = 9,97\,\%$ $\rightarrow$ $\frac{\Delta\eta}{\eta'} = 0,45\,\% < 1\,\%$ ok!

## Problema 4

1. $q_c = h(T_{\infty} - T_i) = 169,82(280 - 20) = 44153,2\,\frac{W}{m^2}$ ($\dot Q_c = 20\,W$)

$q^{\rightarrow}_{rad\,12} = \frac{\sigma(T_1^4 - T^4)}{\frac{1 - \varepsilon_1}{\varepsilon_1 A_1} + \frac{1}{F_{12} A_1} + \frac{1 - \varepsilon_2}{\varepsilon_2 A_2}} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1 - \varepsilon_1}{\varepsilon_1} + 1 + \frac{1 - \varepsilon_2}{\varepsilon_2}\frac{A_1}{A_2}} = \sigma\varepsilon_1(T_1^4 - T_2^4)$

$F_{12} = 1$ conv! $\quad A_1/A_2 \simeq 0$ $A_1 \ll A_2$

$q^{\leftarrow}_{rad\,21} = -q^{\rightarrow}_{rad\,12} = \sigma\varepsilon_1(T_2^4 - T_1^4) = 5,67 \cdot 10^{-8} \times 0,8\,(553,15^4 - 293,15^4) = 3911,6\,W/m^2$ $\rightarrow$ $\dot Q_{rad} = 1,77\,kW$

2. $\frac{q_{rad}}{q_{conv}} = \frac{3911,6}{44153,2} = 8,9\,\%$ $\rightarrow$ flusso radiativo trascurabile!

3. $Re_3 = \frac{\rho u_m D}{\mu} = \frac{0,6389 \times 19,6 \times 0,012}{28,8 \cdot 10^{-6}} = 5210,5$

$Pr = \frac{\mu c_p}{k} = \frac{28,8 \cdot 10^{-6} \times 1040}{0,044} = 0,682$

$Nu = 2 + \left[0,44(5210,5)^{0,5} + 0,0066(5210,5)^{0,667}\right](0,682)^{0,4} = 46,31$

$\rightarrow h = \frac{Nu\,k}{D} = \frac{46,31 \times 0,044}{0,012} = 169,87\,\frac{W}{m^2 K}$

$Bi = \frac{h L_c}{k_{al}} = \frac{h\frac{D}{6}}{k_{al}} = \frac{169,82 \times 0,012}{6 \times 364} = 0,000\,93$ $\rightarrow$ Mod. PAR. conc. V

$\rho V c \frac{dT}{dt} = -hS(T - T_{\infty})$

$\int_{T_i}^{T_f} \frac{dT}{T - T_{\infty}} = -\frac{hS}{\rho V c}\int_{t_i=0}^{t_f} dt \rightarrow \ln\frac{T_f - T_{\infty}}{T_i - T_{\infty}} = -\frac{6h}{\rho D c}\,t$

$t = \frac{\rho D c}{6h} \ln\frac{T_{\infty} - T_i}{T_{\infty} - T_f} = \frac{8900 \times 380 \times 0,012}{6 \times 169,82} \ln\frac{280 - 20}{280 - 275} = 157,4\,s$

(39,83 — 3,95)