Soluzione del compito di Fisica Tecnica del 6 luglio 2015

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

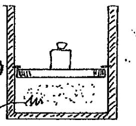
Problema 1

Aria G.P. biatom.

$R^* = \frac{8314{,}5}{29} = 286{,}7 \frac{J}{kg}$

$c_v^* = \frac{5}{2}R^* = 716{,}8 \frac{J}{K\,kg}$

$c_p^* = \frac{7}{2}R^* = 1003{,}5$ "



1. $U_2 - U_1 = L_{el}^{\leftarrow} - \cancel{Q}^{\to 0}$ Ad.

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

(GP) $\to Mc_v(T_2 - T_1) = Wt$

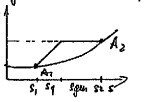
$T_2 = T_1 + \frac{Wt}{Mc_v} = 20 + \frac{10 \times 100}{0{,}002 \times 716{,}8} = 716{,}6\,°C = 990{,}73\,K$

$p_2 = \frac{MR^*T_2}{V_2} = \frac{0{,}002 \times 286{,}7 \times 990{,}73}{0{,}84 \cdot 10^{-3}} = 6{,}8 \cdot 10^5\ Pa$

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

$S_{gen} = S_2 - S_1 - S_q^{A_t}$ poiché $S_q^{A_t} = 0$ il processo $A_1 \to A_2$ è irreversibile!

3.



4. $A_2 \to A_3$ $U_3 - U_2 = \cancel{Q_{23}}^{0} - L_{23}^{\to}$; $L_{23}^{\to} = \int_{z_2}^{z_3} F_p\,dz = F_p(z_3 - z_2)\frac{A}{A} = \frac{F_p}{A}(V_3 - V_2) = p_3(V_3 - V_2)$

(GP) $Mc_v(T_3 - T_2) = -p_3(V_3 - V_2)$

$Mc_vT_3 + p_3V_3 = Mc_vT_2 + p_3V_2$

$Mc_vT_3 + MR^*T_3 = Mc_vT_2 + p_3V_2 \to M\overbrace{(c_v + R^*)}^{c_p}T_3 = Mc_vT_2 + p_3V_2$

$T_3 = \frac{c_v}{c_p}T_2 + \frac{p_3V_2}{Mc_p} = \frac{990{,}73}{1{,}4} + \frac{1{,}8 \cdot 10^5 \times 0{,}84 \cdot 10^{-3}}{0{,}002 \times 1003{,}5} = 783\,K = 509{,}85\,°C$

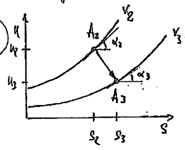
$V_3 = \frac{MR^*T_3}{p_3} = \frac{0{,}002 \times 286{,}7 \times 783}{1{,}8 \cdot 10^5} = 2{,}5 \cdot 10^{-3}\ m^3$

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

5. $S_3 - S_2 = \cancel{S_{q23}}^{0\ Ad} + S_{gen,23}$

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

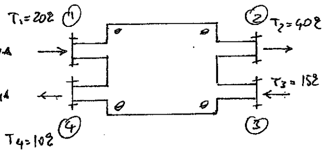
6.



$u_2 > u_3 > u_1$

$s_3 > s_2 > s_1$

Problema #2



1. $\frac{dM^{AR}}{dt} = \dot m_1^{\leftarrow} - \dot m_2^{\to} = 0 \to \dot m_2^{\to} = \dot m_1^{\leftarrow}$ (SS)

$\frac{dM^{AC}}{dt} = \dot m_3^{\leftarrow} - \dot m_4^{\to} = 0 \to \dot m_4^{\to} = \dot m_3^{\leftarrow}$

$\frac{dE}{dt} = \dot m_1 h_1 - \dot m_2 h_2 + \dot m_3 h_3 - \dot m_4 h_4 - \cancel{\dot Q'^{\to}}^{0\ (AD)} - \cancel{\dot L'^{\to}}^{0} \overset{(S.S)}{=} 0$

$\dot m_3^{\leftarrow} = \frac{h_2 - h_1}{h_3 - h_4}\dot m_2^{\to} = \frac{c_p(T_2 - T_1)}{c(T_3 - T_4) + v\cancel{(p_3 - p_4)}^{0}}\dot m_2^{\to}$ (GP) (L.I)

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

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

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

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

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

2. $\frac{dS}{dt} = \dot m_1 s_1 - \dot m_2 s_2 + \dot m_3 s_3 - \dot m_4 s_4 - \cancel{\dot S_{Q_0}^{\to}}^{0\ (AD)} + \dot S_{gen} \overset{(S.S)}{=} 0$

$\dot S_{gen} = -\dot m_3(s_3 - s_4) + \dot m_1(s_2 - s_1) = -\dot m_3 c \ln\frac{T_3}{T_4} + \dot m_1 c_p\left(\ln\frac{T_2}{T_1} - \frac{R^*}{c_p}\cancel{\ln\frac{p_2}{p_1}}^{0}\right) =$ (L.I) (G.P)

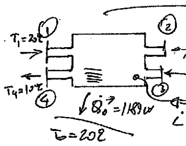
$= -0{,}956 \times 4200 \ln\frac{288{,}15}{283{,}15} + 1 \times 1003{,}5 \ln\frac{313{,}15}{293{,}15} = -4{,}055 \frac{W}{K} < 0$

70,284 66,229

NO!! NON PUO' FUNZIONARE!

3. $\frac{dE}{dt} = \underbrace{\dot m_1 h_1 - \dot m_2 h_2 + \dot m_3 h_3 - \dot m_4 h_4}_{=0} - \dot Q_0^{\to} + \dot L^{\leftarrow} \overset{(SS)}{=} 0$

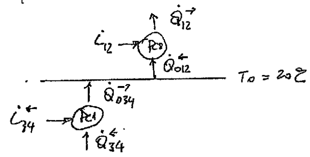
$\frac{dS}{dt} = \dot m_1 s_1 - \dot m_2 s_2 + \dot m_3 s_3 - \dot m_4 s_4 - \dot S_{Q_0}^{\to} + \cancel{\dot S_{gen}}^{0\ (RE)} \overset{(SS)}{=} 0$



$\dot L^{\leftarrow} = \dot Q_0^{\to} = 1189\ W$

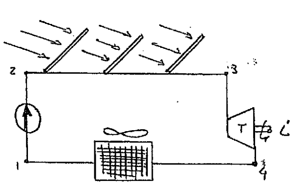
$\dot S_{Q_0} = \dot m_3(s_3 - s_4) - \dot m_1(s_2 - s_1) = 4{,}055 \frac{W}{K} \to \dot Q_0^{\to} = T_0 \dot S_{Q_0}^{\to} = 1189\ W$ (q.t.c)

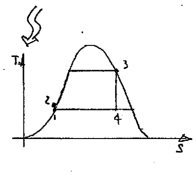
4.



$\dot Q_{034}^{\to} - \dot Q_{012}^{\leftarrow} = (\cancel{\dot Q_{34}} + \dot L_{34}) - (\cancel{\dot Q_{12}} - \dot L_{12}) = \dot L_{34} + \dot L_{12}$?

Problema #3





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

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

$\frac{dS^T}{dt} = \dot m_3 s_3 - \dot m_4 s_4 - \cancel{\dot S_q}^{0\ Ad} + \cancel{\dot S_{gen}}^{0\ Re} = 0$

$\begin{cases} L_{34}^{T\to} = \dot m_3(h_3 - h_4) \\ s_3 = s_4 \end{cases}$ $\dot m_3 = \frac{\dot L^{T\to}}{h_3 - h_4}$

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

$s_4 = s_{ls}(p_1) + x_4(s_{vs} - s_{ls})_{p=p_1} = s_3 \to x_4 = \frac{s_3 - s_{ls}(p_1)}{(s_{vs} - s_{ls})_{p=p_1}}$

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

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

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

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

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

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

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

4. $\dot L^{P\leftarrow} = \dot m(h_2 - h_1) \overset{(L.I)(Re)}{=} \dot m v(p_2 - p_1) = 0{,}489 \times 0{,}00082(1{,}68 - 0{,}6) \cdot 10^6 = 430\ W$

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

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

Problema # 4

1. $q_c = h(T_{p0} - T_i) = 169{,}82(280 - 20) = 44\,153{,}2 \frac{W}{m^2}$ $\to \dot Q_c = 20\ W$

$q_{rad_{12}}^{\to} = \frac{\sigma(T_1^4 - T^4)}{\frac{1}{A_1}\left[\frac{1-\varepsilon_1}{\varepsilon_1 A_1} + \frac{1}{F_{12}A_1} + \frac{1-\varepsilon_2}{\varepsilon_2 A_2}\right]} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1-\varepsilon_1}{\varepsilon_1} + 1 + \frac{1-\varepsilon_2}{\varepsilon_2}\frac{A_1}{A_2}} = \sigma\varepsilon_1(T_1^4 - T_2^4)$

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

$q_{rad_{21}}^{\leftarrow} = -q_{rad_{12}}^{\to} = \sigma\varepsilon_1(T_2^4 - T_1^4) = 5{,}67 \cdot 10^{-8} \times 0{,}8\,(553{,}15^4 - 293{,}15^4)$

$= 3911{,}6\ W/m^2 \to Q_{rad} = 1{,}77\,W$

2. $\frac{q_{rad}}{q_{conv}} = \frac{3911{,}6}{44\,153{,}2} = 8{,}9\,\% \to$ flusso radiativo trascurabile!

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

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

$Nu = 2 + \left[0{,}44\,(5210{,}5)^{0{,}5} + 0{,}066\,(5210{,}5)^{0{,}667}\right](0{,}682)^{0{,}4} = 46{,}31$

$\to h = \frac{Nu\,k}{D} = \frac{46{,}31 \times 0{,}044}{0{,}012} = 169{,}82 \frac{W}{m^2K}$

$Bi = \frac{hL_c}{k_{al}} = \frac{hD}{6k_{al}} = \frac{169{,}82 \times 0{,}012}{6 \times 364} = 0{,}00093 \to$ MOD. PAR. CONC. !

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

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

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

39,83 3,95