

Soluzione del compito di Fisica Tecnica del 9 settembre 2015

ATTENZIONE: la presente soluzione è puramente indicativa e non si escludono errori o omissioni. La valutazione della prova scritta si basa in modo paritario sullo svolgimento formale e su quello numerico. Per essere ammessi all'orale è necessario riportare una votazione dello scritto di almeno 16/30, non ci sono penalità per chi riporta una votazione non inferiore a 10/30

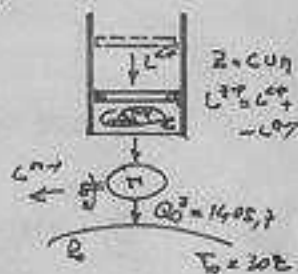
PROBLEMA #1

1)  $\exists P_{II} \Leftrightarrow (S_2 - S_1)^c \geq 0$

$(S_2 - S_1)^c = (S_2 - S_1)^A + (S_2 - S_1)^P$   
 $= \dot{m}_A c_p \left( \ln \frac{T_2^A}{T_1^A} - \frac{P}{c_p} \ln \frac{P_2}{P_1} \right) + \dot{m}_P c_p \ln \frac{T_2^P}{T_1^P}$

$\frac{11.9 \cdot 10^{-3} \cdot 1003.5}{29.3} \left( \ln \frac{373}{293} - \frac{2}{7} \ln \frac{10}{1} \right) + 0.002 \cdot 700 \ln \frac{573}{293} = -4.975 + 0.338 = -4.637 \text{ J/K} < 0 \rightarrow \nexists P_{II}$

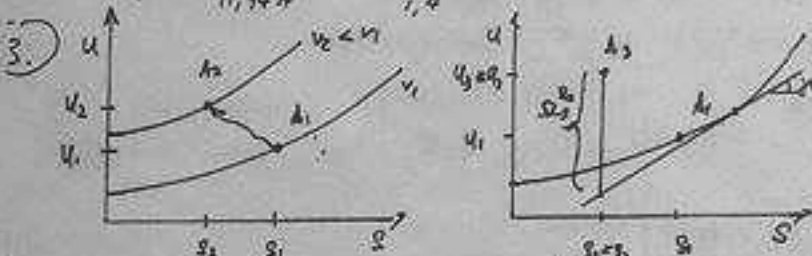
$\dot{m}_A = \frac{P_1 V_1}{R T_1} = \frac{10^5 \cdot 0.01}{286.7 \cdot 293} = 11.9 \cdot 10^{-3} \text{ kg/s}$   
 $R^* = \frac{8314.5}{29} = 286.7 \text{ J/kgK}$   
 $c_p = \frac{7}{2} R^* = 1003.5 \text{ J/kgK}$   
 $c_v = \frac{5}{2} R^* = 716.8 \text{ J/kgK}$



2)  $(U_2 - U_1)^c = -Q_0^{c*} + L^{c*}$   
 $(S_2 - S_1)^c = -S_0^{c*} + S_0^{c*}$   
 $(U_2 - U_1)^c + (U_1 - U_1)^c = -Q_0^{c*} + L^{c*}$   
 $(S_2 - S_1)^c + (S_1 - S_1)^c = -Q_0^{c*} + L^{c*}$

$L^{c*} = (U_2 - U_1)^c + Q_0^{c*} = (U_2 - U_1)^A + (U_2 - U_1)^P + Q_0^{c*}$   
 $Q_0^{c*} = -T_0(S_2 - S_1)^c = +4.637 \cdot 303.15 = 1405.7 \text{ J}$

$L^{c*} = \dot{m}_A c_p (T_2^A - T_1^A) + \dot{m}_P c_p (T_2^P - T_1^P) + Q_0^{c*} = (\dot{m}_A c_p + \dot{m}_P c_p)(T_2 - T_1) + Q_0^{c*}$   
 $L^{c*} = (11.9 \cdot 10^{-3} \cdot 1003.5 + 0.002 \cdot 700)(100 - 20) + 1405.7 = 2473 \text{ J} = L^{c*} - L^{A*}$



3)  $(U_2 - U_1)^c = -Q_0^{c*} + L^{c*}$   
 $(U_2 - U_1)^A + (U_1 - U_1)^c = -Q_0^{c*} + L^{c*}$   
 $(S_2 - S_1)^c = -S_0^{c*} + S_0^{c*}$   
 $(S_2 - S_1)^A + (S_1 - S_1)^c = -Q_0^{c*} + L^{c*}$

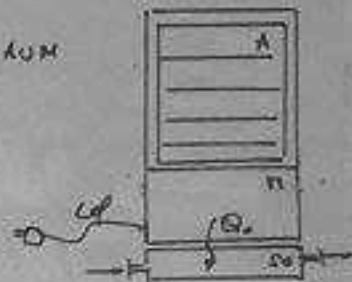
$L^{c*} = (U_2 - U_1)^A + Q_0^{c*} = (956.3 + 1508.2) \text{ J} = 2464.5 \text{ J}$   
 $Q_0^{c*} = -T_0(S_2 - S_1)^A = +4.975 \cdot 303.15 = 1508.2 \text{ J}$

$\epsilon_Q = \left| 1 - \frac{Q_0^c}{Q_0} \right| = \left| 1 - \frac{1508.2}{2464.5} \right| = 38.9\% < 60\% \text{ ok!}$

$\epsilon_L = \left| 1 - \frac{L^c}{L} \right| = \left| 1 - \frac{2464.5}{2473} \right| = 0.38\% < 10\% \text{ ok!}$

PROBLEMA #2

Z = CUM



1-2  $(U_2 - U_1)^c = L^{c*} + Q_0^{c*}$   
 $(S_2 - S_1)^c = S_0^{c*} + S_0^{c*}$

$(U_2 - U_1)^c = (U_2 - U_1)^A + (U_2 - U_1)^P = \dot{m} c_p (T_2 - T_1)^c$   
 $(S_2 - S_1)^c = (S_2 - S_1)^A + (S_2 - S_1)^P = \dot{m} c_p \ln \frac{T_2}{T_1}$

$Q_0^{c*} = \frac{Q_0^{A*}}{c_p T_0}$

$Q_0^{c*} = (U_2 - U_1)^c - L^{c*} = \dot{m} c_p (T_2 - T_1)^c - L^{c*}$   
 $S_0^{c*} = (S_2 - S_1)^c - S_0^{c*} = \dot{m} c_p \ln \frac{T_2}{T_1} - \frac{Q_0^{c*}}{T_0}$

$Q_0^{c*} = 25 \cdot 4186 (5 - 20) - 9.2 \cdot 3.6 \cdot 10^6 = -2289750 \text{ J}$   
 $S_0^{c*} = 25 \cdot 4186 \ln \frac{278.15}{293.15} + \frac{-2289750}{323.15} = 1589.1 \text{ J/K}$

2)  $U_2 - U_1 = L^{c*} + Q_0^{c*}$   
 $S_2 - S_1 = S_0^{c*} + S_0^{c*} = \frac{Q_0^c}{T_0}$   
 $L^{c*} = (U_2 - U_1) - T_0(S_2 - S_1)$   
 $Q_0^c = T_0(S_2 - S_1)$

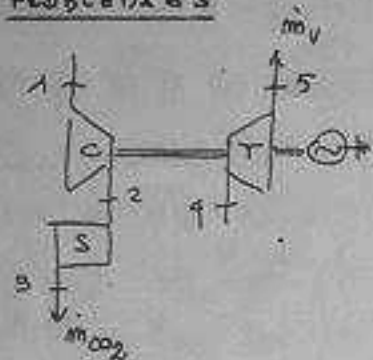
$L^{c*} = \dot{m} c_p (T_2 - T_1) - \dot{m} T_0 \ln \frac{T_2}{T_1}$

$= -1569750 + 323.15 \cdot 5496.6 = 205484 \text{ J} = 0.057 \text{ kWh}$   
 $1776.254$

$\dot{m} = 50 \cdot 0.5 = 25 \text{ kg/s}$

FUNZIONA? DA S' IRREV P

PROBLEMA 3



(a) VAP. SURR.:

$p = 35 \text{ MPa}$

T (°C)	$\rho$ (kg/m³)	$\rho$ (kg/kgK)
350	3104,0	6,6579
400	3222,3	6,8405

$$\rho_4 = 3104 + 0,4(3222,3 - 3104,0) = 3151,3 \text{ kg/m}^3$$

$$\rho_4 = 6,6579 + 0,4(6,8405 - 6,6579) = 6,7309 \text{ kg/m}^3$$

(3) VAP. UNDO:  $\rho_5 = (1 - \alpha_5)\rho_{5,LS} + \alpha_5\rho_{5,VS} = 0,15 \cdot 251,40 + 0,85 \cdot 2609,7 = 2256,0 \text{ kg/m}^3$

$\rho_5 = (1 - \alpha_5)\rho_{5,LS} + \alpha_5\rho_{5,VS} = 0,15 \cdot 0,8320 + 0,85 \cdot 7,3086 = 6,8471 \text{ kg/m}^3 > \rho_4 \rightarrow \text{ESP. ADIAB. 1.2.25V.}$

$\dot{L}_{4,T} = \dot{m}_v(\rho_4 - \rho_5) = \frac{100}{3600}(3151,3 - 2256,0) = 24,9 \text{ kW}$

$\dot{L}_{GE} = \dot{L}_{4,T} - \dot{L}_{T,C} = 24,9 - 4 = 20,9 \text{ kW}$

$\alpha_{54} = \frac{\rho_4 - \rho_{5,LS}}{\rho_{5,VS} - \rho_{5,LS}} = \frac{6,7309 - 0,8320}{7,3086} = 0,834 < \alpha_5$  (OK)

$\rho_{53} = (1 - \alpha_{54})\rho_{5,LS} + \alpha_{54}\rho_{5,VS} = 0,166 \cdot 251,40 + 0,834 \cdot 2609,7 = 2218,2 \text{ kg/m}^3$

$\eta_{4,T} = \frac{\rho_4 - \rho_5}{\rho_4 - \rho_{53}} = \frac{3151,3 - 2256,0}{3151,3 - 2218,2} = 0,96$

$c_{p,CO_2} = \frac{\gamma}{2} \frac{R_u}{M_m} = \frac{1,4}{2} \frac{8314}{44} = 661,3 \frac{J}{kgK}$  ( $0 = c = 0$ )

$\dot{L}_{T,C} = \dot{m}_{CO_2} c_{p,CO_2} (T_2 - T_1) \rightarrow T_2 = T_1 + \frac{\dot{L}_{T,C}}{\dot{m}_{CO_2} c_{p,CO_2}}$

$= 15 + \frac{4000 \cdot 3600}{25 \cdot 661,3} = 886,01 \text{ °C}$

$\dot{Q}_3 = \dot{m}_{CO_2} c_{p,CO_2} (T_3 - T_2) = \frac{25}{3600} \cdot 661,3 \cdot (10 - 886,01) = -3869,3 \text{ W}$

$T_{23} = T_1 \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} = 288,15 \cdot 100^{0,4/1,4} = 1074,11 \text{ K} = 800,96 \text{ °C} < T_2$

$\eta_{4,C} = \frac{T_{23} - T_3}{T_2 - T_3} = \frac{800,96 - 15}{886,01 - 15} = 0,90$

PROBLEMA 4

(1)  $\dot{Q}_{conv} = h \times D_3 L (T_3 - T_0)$

$h = \frac{Nu \cdot k}{D_3}$

$Re = \rho v \cdot D_3 = 3,784 \cdot 10^3 \times 97 = 3,67 \cdot 10^7$

$Pr = \frac{\rho c_p (T_3 - T_0) \mu}{k} = \frac{(1181)^3 \cdot 9,21 \cdot 10^3 \cdot (34 - 15) \cdot (0,26)^2}{(11,09 \cdot 10^{-3})^2} = 3,184 \cdot 10^7$

$Pr = \frac{\mu c_p}{k} = \frac{13,01 \cdot 10^{-6} \times 1007,2}{0,0273} = 0,7$

$Nu = \left\{ 1 + \frac{0,387(3,67 \cdot 10^7)^{1/4}}{[1 + (0,59/0,3)^{1/4}]^{1/4}} \right\}^2 = 42,5$

$\hookrightarrow h = \frac{42,5 \cdot 0,0273}{0,26} = 4,46 \text{ W/m}^2\text{K}$

$\hookrightarrow \dot{Q}_{conv} = 4,46 (5 \cdot 0,26 \times 10) (34 - 15) = 692,9 \text{ W}$

$\dot{Q}_{rad} = \sigma \varepsilon \times D_3 L (T_3^4 - T_0^4) = 5,67 \cdot 10^{-8} \times 9,15 \times 8,16 \text{ m} (307,15^4 - 288,15^4) = 92,9 \text{ W}$

$\varepsilon = \alpha = 1 - \rho = 0,1$

$\dot{Q}_{diff} = 692,9 + 92,9 = 785,8 \text{ W}$

(2)  $R_1 = \frac{D_1}{2} - s_1 = \frac{6}{2} - 0,5 = 2,5 \text{ cm}$

$h = 0,05 \text{ m}$

$R_3 = \frac{D_3}{2} + s_3 = \frac{6}{2} + 10 = 13 \text{ cm}, D_3 = 0,26 \text{ m}$



$T_1 = T_3 + \dot{Q}_{diff} (R_{k,1} + R_{k,2}) = T_3 + \dot{Q}_{diff} \left[ \frac{h(D_1/D_3)}{2k_1 L} + \frac{h(D_2/D_3)}{2k_2 L} \right]$

$= 34 + 785,9 \left[ \frac{0,05 \cdot 145}{25 \cdot 20 \times 10} + \frac{0,05 \cdot 750}{25 \cdot 0,05 \times 10} \right] = 400 \text{ °C} = 673,1 \text{ K}$

$0,466895$