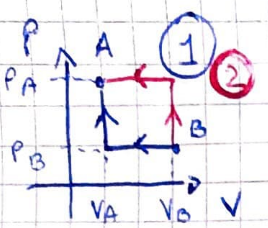
Esercizio 1

$p_B = \frac{1}{2} p_A \qquad \Delta T_{BA} = 900\,K \qquad \Delta T_{AB} = -900\,K \qquad c_V = \frac{3}{2} R$



$Q_2 = \frac{6}{5} Q_1$

1° principio

(1) $\rightarrow \Delta U_1 + L_1 = Q_1 \rightarrow m c_V \Delta T_{BA} + (L_{isob} + L_{isoc}) = Q_1$, con $L_{isob} = p_B \cdot (V_A - V_B)$, $L_{isoc} = 0$

(2) $\rightarrow \Delta U_2 + L_2 = \frac{6}{5} Q_1 \rightarrow m c_V \Delta T_{BA} + p_A (V_A - V_B) = \frac{6}{5} Q_1$

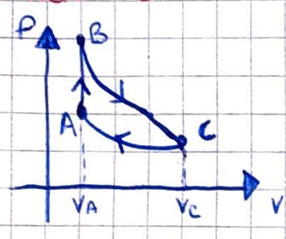
$p_A (V_A - V_B) = \frac{6}{5} Q_1 - m c_V \Delta T$

(1) $\rightarrow m c_V \Delta T + \frac{p_A}{2}(V_A - V_B) = Q_1 \Rightarrow m c_V \Delta T + \frac{1}{2}\left(\frac{6}{5} Q_1 - m c_V \Delta T\right) = Q_1$

$\Rightarrow \frac{1}{2} m c_V \Delta T + \frac{3}{5} Q_1 = Q_1 \Rightarrow \frac{1}{2} m c_V \Delta T = \left(-\frac{3}{5} + 1\right) Q_1 \rightarrow Q_1 = \frac{5}{4} m \frac{3}{2} R \cdot 900\,K = +14023\,J$

è positivo ↑ ASSORBITO

Esercizio 2



$\eta = \frac{L}{Q_{ASS}} \rightarrow \eta = 1 - \frac{|Q_{ced}|}{|Q_{ASS}|}$

$\frac{T_B}{T_A} = 2$

$c_V = \frac{5}{2} R \quad \gamma = \frac{7}{5}$ — biatomico

$c_V = 3/2 \quad \gamma = 5/3$ — monoatomico

$Q_{BC} = 0$ (adiabatica)

$Q_{AB} = \Delta U = m c_V (T_B - T_A)$ → positivo, calore assorbito ($T_B - T_A > 0$)

$Q_{CA} = L_{CA} = m R T_A \ln\left(\frac{V_A}{V_C}\right)$ $\quad V_A < V_C$ → negativo, calore ceduto

$= m R T_A \ln\left(\frac{V_C}{V_A}\right)$

$\eta = 1 - \frac{R}{c_V (T_B/T_A - 1)} \cdot \ln\left(\frac{V_C}{V_A}\right) = 1 - \frac{m R T_A \ln \frac{V_C}{V_A} \cdot \frac{1}{T_A}}{m c_V (T_B - T_A) \cdot \frac{1}{T_A}} = 1 - \frac{m R \ln \frac{V_C}{V_A}}{m c_V \left(\frac{T_B}{T_A} - 1\right)}$

ADIABATICA BC $\rightarrow T_B V_B^{\gamma-1} = T_C V_C^{\gamma-1}$

$T_C = T_A$, $V_A = V_B$ $\rightarrow T_B V_A^{\gamma-1} = T_A V_C^{\gamma-1} \Rightarrow \frac{V_C}{V_A} = \left(\frac{T_B}{T_A}\right)^{\frac{1}{\gamma-1}}$

$\eta = 1 - \frac{R}{c_V}\left(\frac{T_B}{T_A} - 1\right)^{-1} \ln\left[\left(\frac{T_B}{T_A}\right)^{\frac{1}{\gamma-1}}\right] \Rightarrow 1 - \frac{R}{c_V}\left(\frac{T_B}{T_A} - 1\right)^{-1}\left(\frac{1}{\gamma-1}\right) \ln \frac{T_B}{T_A} \Rightarrow 1 - \frac{c_V}{c_V}\left(\frac{T_B}{T_A} - 1\right)^{-1} \ln \frac{T_B}{T_A}$

$\frac{R}{\gamma - 1} = \frac{R}{\frac{c_p}{c_V} - 1} = \frac{R}{\frac{c_p - c_V}{c_V}} = \frac{R\, c_V}{c_p - c_V} = \frac{R\, c_V}{R}$, con $c_p - c_V = R$

$\eta = 1 - \left(\frac{T_B}{T_A} - 1\right)^{-1} \ln \frac{T_B}{T_A} = 0{,}307 \approx 31\%$

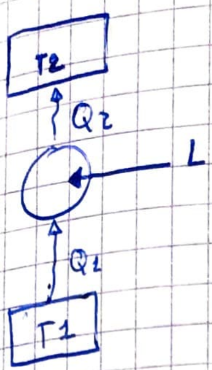
↑ non dipende dal tipo di gas (se è biatomico o monoatomico)

Esercizio 3

$T_1 = 273\ K$ $\quad T_2 = 313\ K$

Teorema di Clausius → Reversibile → ΔS entropia $= \oint \frac{\delta Q}{T}$ (sistema continuo) $\qquad \sum_{i=1} \frac{Q_i}{T_i} = 0$ (sistema discreto)

A ↔ B



Reversibile $\frac{Q_1}{T_1} - \frac{|Q_2|}{T_2} = 0$

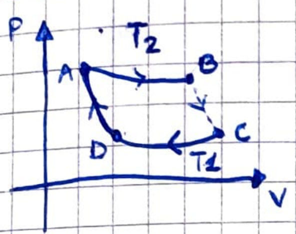
$Q_2 = \frac{T_2}{T_1} Q_1 \qquad L = Q_2 - Q_1 = Q_1\left(\frac{T_2}{T_1} - 1\right)$

$Q_1 = m\lambda \qquad L = m\lambda\left(\frac{T_2}{T_2} - 1\right)$

Costo energia: 0,5/KWh → convertire KWh in J (Joule W·s)

$\text{Costo} \cdot L = m\lambda \text{€}\left(\frac{T_2}{T_1} - 1\right) = 0{,}67\ \text{€}$

Esercizio 4



DA e BC → Q = 0 $\qquad T_1 = 200\ K$, $T_2 = 500\ K$

AB e CD → isoterme

$Q = L \quad (\Delta U = 0) = nRT \ln\left(\frac{V_f}{V_i}\right)$

Q_{AB} → assorbito $\ln\frac{V_f}{V_i} > 0$

Q_{CD} → ceduto $\ln\frac{V_f}{V_i} < 0$

$\eta = 1 - \frac{|Q_c|}{|Q_A|} = 1 - \frac{nRT_1 \ln\left(\frac{V_C}{V_D}\right)}{nRT_2 \ln\left(\frac{V_B}{V_A}\right)}$ → voglio che sia positivo e inverto VD e VC

$\frac{V_C}{V_D} = 2{,}3$

$\eta = 0{,}52$

$\frac{V_B}{V_A} = 2$

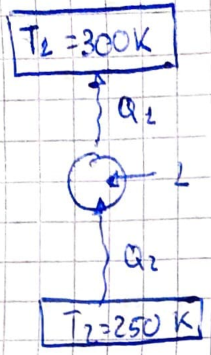
Se fosse reversibile, macchina di Carnot. $\eta_c = 1 - \frac{T_1}{T_2} = 0{,}6$

$\frac{L_{BC}}{L_{DA}} = \frac{-\Delta U_{BC}}{-\Delta U_{DA}} = \frac{nc_v(T_1 - T_2)}{nc_v(T_2 - T_1)} = -1$

$\Delta U = -L$

$L = -\Delta U$

Esercizio 5



$$Q_1 + Q_2 = L$$

$$\Delta S_U = -\frac{Q_2}{T_2} + \frac{Q_1}{T_1} \qquad P = 1{,}2\,KW \qquad n = 4\,giri$$

$$L = Q_1 - Q_2 \Rightarrow Q_1 = L + Q_2$$

$$\Delta S_U = \frac{-Q_2}{T_2} + \frac{L}{T_1} + \frac{Q_2}{T_1}$$

$$\Delta S_U - \frac{L}{T_1} = \left(\frac{1}{T_1} - \frac{1}{T_2}\right) Q_2$$

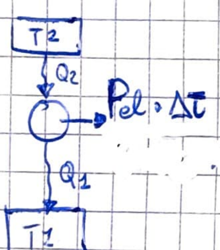
$$Q_2 = \frac{\Delta S_U - \frac{L}{T_1}}{\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} = 900\,J \qquad L = \frac{P}{n}$$

$$P = \frac{L}{T_{emo}} \qquad f = 4\,giri/s$$

$$\frac{P}{f} = \frac{L}{\tau} \cdot \frac{\tau}{n_{giri}} = \quad P = \frac{L}{f}\,n_{giri}$$

$$\begin{cases} Q_2 = Q_1 - L \\ \Delta S_U = -\frac{Q_2}{T_2} + \frac{Q_1}{T_1} \end{cases} \Rightarrow \quad Q_1 = \frac{\Delta S_U - \frac{P}{nT_2}}{\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} = -1200\,J$$

Esercizio 6



$P_{el} = 900\,MW \qquad T_2 = 550\,°C = 823\,K \qquad T_1 = 15\,°C = 288{,}15\,K \qquad \Delta T = 1h$

$\eta = 60\%\ \eta_c$

potere calorifico $c = 7500\,Kcal/Kg$

$\eta = 0{,}6\,\eta_c$ (massimo consentito dalle leggi della Termodinamica.

$$\eta_c = 1 - \frac{T_1}{T_2}$$

$Q_2 = p_c \cdot m$ (potere calorifico) $\qquad L = P_{el} \cdot \Delta T$ (1h) $=$ L svolto dalla macchina in 1 h

$$\eta = \frac{L}{Q_2} \rightarrow Q_2 = \frac{L}{\eta} = p_c \cdot m = \frac{L}{\eta} \Rightarrow m = \frac{L}{\eta\, p_c}$$

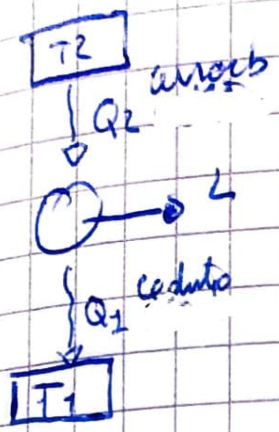
$$m = \frac{P_{el} \cdot \Delta T}{p_c \cdot 0{,}6\left(1 - \frac{T_1}{T_2}\right)} = 2{,}64 \cdot 10^5\,Kg$$ (massa di carbone consumata ogni ora)

Esercizio 7

$T_2 = 800\,°C \qquad T_1 = 300\,°C \qquad P = 10\,kW \qquad \eta = 0{,}6\,\eta_c = 0{,}28$

$\Delta t = 1\,h = 3600\,s$

$\eta_c \rightarrow 1 - \frac{T_1}{T_2}$



$$\eta = \frac{L}{Q_2} = \frac{P\Delta t}{Q_A}$$

$$Q_2 = \frac{P \cdot \Delta t}{\eta} = \frac{P \cdot \Delta t}{0{,}6 \cdot \left(1 - \frac{T_1}{T_2}\right)} = 128{,}6 \cdot 10^6\,J$$

$$\eta = 1 - \frac{Q_1}{Q_2} \Rightarrow Q_1 = (1-\eta) \cdot Q_2 = 92{,}6 \cdot 10^6\,J$$

$$\Delta S_{TOT\,1h} = \frac{-Q_2}{T_2} + \frac{Q_1}{T_1} = 4{,}17 \cdot 10^4\,\frac{J}{K}$$