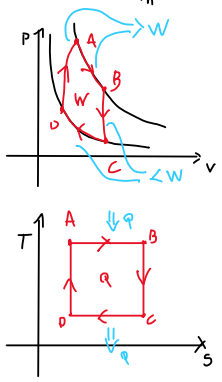
1 - a) Carnot $\Rightarrow \varepsilon = 1 - \frac{T_c}{T_h} = 3.96\%$

b)



c) $COP = \frac{|\dot{Q}_h|}{\dot{W}} = \frac{T_h}{T_h - T_c} \Rightarrow |\dot{Q}_h| = \frac{T_h}{T_h - T_c} \cdot \dot{W} = 12.625\ MJ$

$\dot{Q}_h = 12.625\ GW$

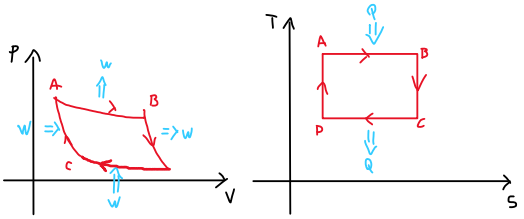
d) $COP = \frac{|\dot{Q}_c|}{\dot{W}} = \frac{T_c}{T_h - T_c} \Rightarrow |\dot{Q}_c| = \frac{T_c}{T_h - T_c} \cdot \dot{W} = 12.125\ MJ$

$\dot{Q}_c = -12.125\ GW$

e) $\dot{Q}_h = \dot{m}\lambda \Rightarrow \dot{m} = \frac{\dot{Q}_h}{\lambda} = 11 \times 10^3\ kg/s$

f) $\Delta S = \overbrace{\Delta S_p + \Delta S_s + \Delta S_c}^{\circlearrowright 0} = 0$

2. $\dot{m} = 10$ $\quad \# = 5$ $\quad$ a)



b) $\Delta \dot{U}_{AB} = \dot{Q}_q + \dot{W}_{AB}$ $\quad$ Isotermica $\Rightarrow \Delta \dot{U}_{AB}$

$|\dot{Q}_q| = |\dot{W}_{AB}| = \int \dot{p} dV = \int \frac{\dot{m}RT}{V} dV = \dot{m}RT_q \cdot \frac{1}{R} = \dot{m}T_q = 4kW$

$\dot{Q}_q = 4kW$

$\dot{Q}_F = -3kW$

c) $\eta = 1 - \frac{T_F}{T_q} = 0.25 \Rightarrow 25\%$

$\dot{W} = \dot{Q}_q - |\dot{Q}_F| = 1kW$ //

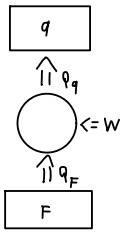
3. Igual ao 2

4. $T_F = -10°C = 263K$

$T_q = 26°C = 298K$

$\Delta t = 30\ min$

$q_F = 10^6\ J$



a) Reversivel $\Rightarrow \Delta S_{uni} = 0$

$\varepsilon = \frac{T_F}{T_q - T_F} = 7.5$

b) $w = \frac{q_F}{\varepsilon} = 0.13 \times 10^6\ J$

$w + q_F = q_q \Rightarrow q_q = 1.13 \times 10^6\ J$

c) $\dot{w} = \frac{W}{\Delta t} = 74\ W$

d) $\dot{Q}_q = \dot{m}\lambda \Rightarrow \dot{m} = \frac{\dot{q}_f}{\Delta t \cdot \lambda} = 2.8\ g/s$

5. a)

$\Delta S = 0 \Rightarrow$ Reversivel $\Rightarrow \varepsilon = \frac{T_f}{T_q - T_f} = 7.37$

b1) $\Delta \dot{U} = \dot{m} c_V \Delta T = \frac{\dot{m}}{M} c_V (3s) = 742\ W$

b2) $T_i V_i^{\gamma - 1} = T_f V_f^{\gamma - 1}$ $\quad \gamma = \frac{c_p}{c_V} = 1 + \frac{R}{c_V}$

$\frac{V_B}{V_A} = 2.1 \sqrt{\frac{T_A}{T_D}} = 0.38$

c) $\Delta \dot{s} = \dot{m} R \ln\left(\frac{V_f}{V_i}\right) = 12.8\ W/K$

$\dot{q}'_{DA} = \Delta \dot{s} \cdot T = 3293\ K$

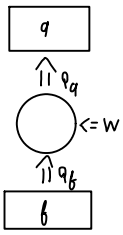
d) $\dot{w} = \frac{\dot{Q}_{DA}}{\varepsilon} = 445\ W \Rightarrow 0.04$ euros

6. $T_q = 22°C$

$T_f = 6°C$

$\dot{w} = 1kW$

$\dot{Q}_q = 4.5\ MJ/h = 1.25\ kW$



$\Delta t = 15\ min$

a) $\dot{w} \cdot \Delta t = 900\ kJ = |w|$

$|\dot{Q}_q| = 4500\ kJ/h \Rightarrow |Q_q| = 4500\ kJ$

$|Q_q| = |w| + |Q_f| \Rightarrow |Q_f| = |Q_q| - |w| = 3600\ kJ$

$\varepsilon = \frac{Q_q}{w} = 5 \Rightarrow 500\%$

b) $\Delta S_{Uni} = \overbrace{\Delta S_{Cdo}}^{0} + \Delta S_{F_f} + \Delta S_{F_q} =$

$= -\frac{q_f}{T_f} + \frac{q_q}{T_q} = 2.4\ kJ/K$

c) $W_R = \frac{Q_q}{\varepsilon_{Max}} = 244\ kJ$

$\varepsilon_{Max} = \frac{T_q}{T_q - T_f}$

Só fazemos trabalho em 25%, mas estamos sempre a perder calor

7- $T_q = 22^\circ C \to 295\,K$

$T_f = 3^\circ C \to 276\,K$

$\dot{W} = 1\,kW$

$\varepsilon = 5$

a) $\varepsilon = \frac{\dot{Q}_q}{\dot{W}} \Rightarrow \dot{Q}_q = 5\,kW$

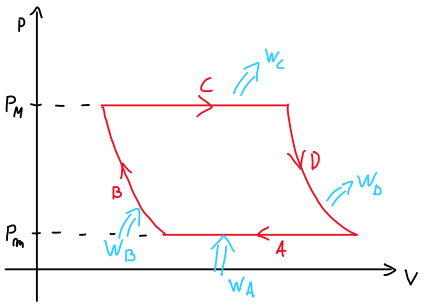
$\dot{Q} = \dot{Q}_q = 5\,kW$

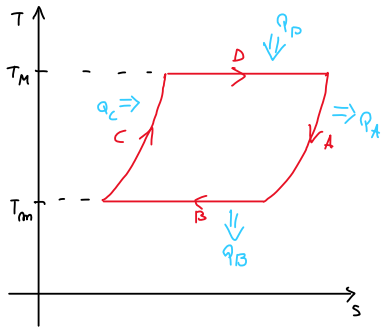
b) $\dot{Q}_f = \dot{Q}_q - \dot{W} = 4\,KW$

c) $\dot{S}_{U_m} = \frac{\dot{Q}_q}{T_q} - \frac{\dot{Q}_f}{T_f} \approx 2.5 \Rightarrow$ Irreversible

d) $\varepsilon_{max} = \frac{T_q}{T_q - T_f} = 15.53$ //

8- a)





b) $Q_A = mc_p \Delta T = -8400\,J$

$Q_B = \Delta U_B - W_B = \overset{0}{mc_v \Delta T} + \int p\,dV = -10 \cdot T_m = -3000\,J$

$Q_C = mc_p \Delta T = 8400\,J$

$Q_D = \Delta U_D - W_D = \underset{0}{mc_v \Delta T} + \int p\,dV = 10\,T_M = 6000\,J$

c) $W_E = W_C + W_D - W_B - W_A$

$W_B = 3000\,J$

$W_D = 6000\,J \Rightarrow W_E = 3000\,J$

$W_A = W_C$

d) $\Delta S_{Univ} = \Delta S_{Cicl_o} + \Delta S_{Fq} + \Delta S_{Ff} = 28 - 14 = 14 \Rightarrow$ Reversible

$\Delta S_{Fq} = \frac{Q_C}{T_M} = -14$

$\Delta S_{Ff} = \frac{Q_A}{T_m} = 28$

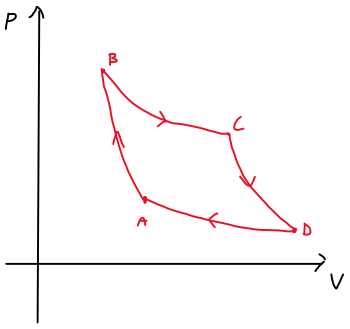
e) $\eta_{max} = 1 - \frac{T_f}{T_q} = \frac{|W|}{|Q_q|} = \frac{|W|}{Q_C + Q_D}$

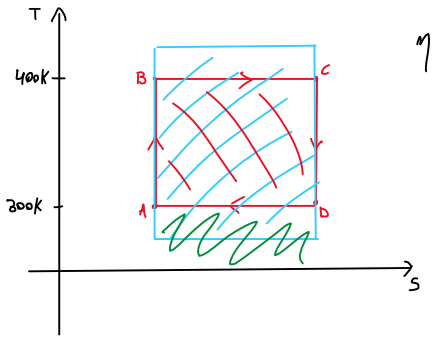
$W_{REV} = \left(1 - \frac{T_f}{T_q}\right)(Q_C + Q_D) = 7200\,J$

$\Delta W = W_{REV} - W_E = 4200\,J$

$T_{amb}\,\Delta S_{Univ} = 4200\,J$

9-





$\eta = \frac{\times}{\times + n}$

a1) $\Delta S_{AB} = 0$ $\Delta S_{CD} = 0$

$Q_{AB} = 0$ $Q_{CD} = 0$

$Q_{BC} = \overset{0}{\Delta U_{BC}} - W_{BC} =$

$= -W_{BC} = -\int p\,dV = mRT\,ln\left(\frac{V_B}{V_C}\right) =$

$= 23\,KJ$

$\Delta S_{BC} = \frac{Q_{BC}}{T} = 57.6$

$Q_{DA} = \overset{0}{\Delta U_{DA}} - W_{DA} =$

$= -W_{DA} = mRT\,ln\left(\frac{V_D}{V_A}\right)$

$Q_{DA} = -17.3\,KJ$

$\Delta S_{DA} = \frac{Q_{DA}}{T} = -57.6$

a2) $\Delta S_{Fq} = \frac{Q_{Fq}}{T_q} = \frac{Q_{BC}}{420}$

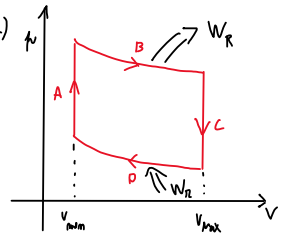
$\Delta S_{Ff} = \frac{Q_{Ff}}{T_f} = \frac{Q_{DA}}{280}$

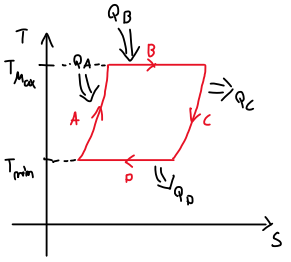
$\Rightarrow \Delta S = \Delta S_{Fq} + \Delta S_{Ff} + \overset{0}{\Delta S_{Cicl_o}} = 7\,JK^{-1}$

a3) $\eta = \frac{1}{4}$

$\eta_{max} = 1 - \frac{T_f}{T_q} = \frac{1}{3}$

10) a)





b) $W_A = W_C = 0$

$W_B = W_R \rightarrow$ Realizado

$$W_B = -\int P\,dV = -\int \frac{nRT}{V}\,dV = -nRT\ln\left(\frac{V_f}{V_i}\right) =$$

$$= -n \cdot R \cdot T_{max} \cdot \ln\left(e^{\frac{12}{R}}\right) = -10 \cdot 1200 = -12\,Ky$$

$W_D = W_n \rightarrow$ recebido

$$W_D = -\int P\,dV = -nRT\ln\left(\frac{V_f}{V_i}\right) = -n \cdot R \cdot T_{min} \cdot \ln\left(e^{-W_D/R}\right) =$$

$$= 10 \cdot 600 = 6\,ky$$

c) $Q_A = -Q_C = mC_V\Delta T = 1 \cdot 20(1200 - 600) = 12\,Ky$

$\Delta U_B = 0 \rightarrow Q_B = -W_B$

$\Delta U_D = 0 \rightarrow Q_D = -W_D$

d) $\Delta S_{Univ} = \Delta S_{Ciclo} + \Delta S_{Fq} + \Delta S_{Ff} = 10$

$$\Delta S_{Fq} = \frac{Q_A}{T_q} = -10$$

$$\Delta S_{Ff} = \frac{Q_C}{T_f} = 20$$

ou

$$\Delta S = \overbrace{\Delta S_{Ciclo}}^{=0} + \Delta S_{HS} + \Delta S_{CS} = \int \frac{dQ_{HS}}{T_{Max}} + \int \frac{dQ_{CS}}{T_{min}} = -\left(\int \frac{dQ_A}{T_{max}} + \int \frac{dQ_B}{T_{max}}\right) - \left(\int \frac{dQ_C}{T_{min}} + \int \frac{dQ_D}{T_{min}}\right) = -\int \frac{dU_A}{T_M} + \int \frac{dW_B}{T_M} - \int \frac{dU_C}{T_m} + \int \frac{dW_D}{T_m} =$$

$$= -\int_{T_m}^{T_M} \frac{mc}{T_M}\,dT - \int_{T_M}^{T_m} \frac{mc}{T_m}\,dT + \int_{V_m}^{V_M} \frac{P}{T_m}\,dV + \int_{V_M}^{V_m} \frac{P}{T_M}\,dV = mC_V\left(\frac{T_M - T_m}{T_m} - \frac{T_M - T_m}{T_M}\right) + \underbrace{nR\left(\int_{V_m}^{V_M} \frac{dV}{V} - \int_{V_m}^{V_M} \frac{dV}{V}\right)}_{>0} = \frac{1}{2}mC_V = 10\ J/K^{-1}$$

$\Delta S_U > 0 \Rightarrow$ irreversível

l 1) $\eta_{Carnot} = 1 - \frac{T_m}{T_M} = 0.5 \Rightarrow 50\%$

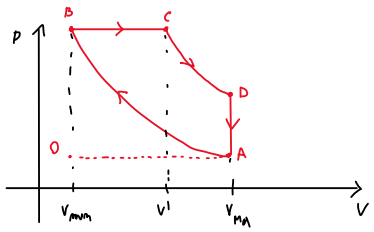
$$\eta = \frac{|W|}{Q_h} = \frac{|W_B + W_D|}{Q_A + Q_B} = \frac{|-12+6|}{12+12} = 0.25 \Rightarrow 25\%$$

l 2) Eliminam a irreversibilidade

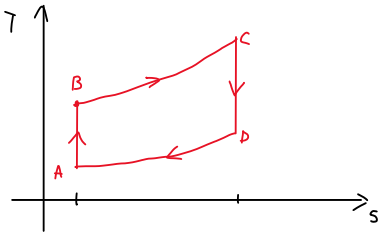
13. $R = \frac{V_M}{V_m} = 16$

$V' = 2.5 V_m$

a)



OA: admissão
AB: compressão adiabática
B: injeção de combustível
BC: expansão isobárica (combustão)
CD: escape adiabático
DA: diminuição isocórica
AO: escape



b) AB e CD $\Rightarrow$ adiabática $\Rightarrow dS = 0$

BC $\Rightarrow$ Isobárica $\Rightarrow dQ = T dS = mc_p dT \Rightarrow T = \alpha e^{\frac{S}{mc_p}}$

DA $\Rightarrow$ Isométrica $\Rightarrow dQ = T dS = mc_v dT \Rightarrow T = \beta e^{\frac{S}{mc_v}}$

c) $\eta = \frac{|W|}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h} =$

$Q_h = mc_p (T_C - T_B)$

$Q_C = mc_v (T_A - T_D)$

$= 1 - \frac{c_v}{c_p} \frac{T_A - T_D}{T_C - T_B} = 1 - \frac{5}{7} \left(2.5\,R\right) \cdot \left(\left(\frac{2.5}{R}\right)^{\frac{5}{7}} - \frac{1}{p^{5/7}} \right) \approx 0.59$