Exercício 32 (Tipler) $PV = nRT$ $c_V = \frac{5}{2}R$; $c_p = \frac{7}{2}R$; $\gamma = \frac{7}{5}$

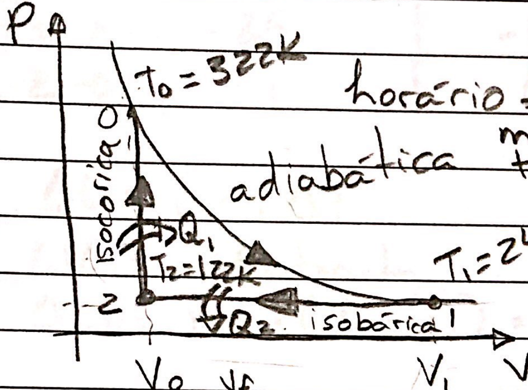
1 mol de gás ideal diatômico $V_1 = 20L$

Ciclo (i) expansão adiabática $V_0 = 10L \rightarrow P_1 = 1atm$

(ii) compressão a Pconst. $\rightarrow V_2 = 10L$

(iii) aquecimento a Vconst $\rightarrow V_0, P_0$

Determine $e = ?$ $\Rightarrow e = \frac{W}{Q_Q}$



horário $\Rightarrow W > 0$ máquina térmica

(i) $Q_1 = 0 \Rightarrow \Delta U_1 = -W_1$

$PV^{\gamma} = const$ e $TV^{\gamma-1} = const$

onde $\gamma = 1{,}4$

(ii) $\Delta U_2 = Q_2 - W_2$

$W_2 = P_1 \Delta V = P_1 (V_2 - V_1)$

(iii) $\Delta V = 0 \Rightarrow W_3 = 0 \Rightarrow \Delta U_3 = Q_3$

$$W = \int_{V_i}^{V_f} P\,dV \; ; \; \underset{\text{isocórico}}{Q = nc_V \Delta T} \text{ e } \underset{\text{isobárico}}{Q = nc_p \Delta T}$$

Estado (1) $\Rightarrow P_1 = 1atm$ e $V_1 = 20L$ $P_1V_1 = nRT_1$

$$T_1 = \frac{P_1V_1}{nR} = \frac{1 \times 20}{1 \times 0{,}082} = 244\,K$$ $R = 0{,}082$ atm.L

$T_1 = 244K$

Estado (0) $\Rightarrow V_0 = 10L$ $P_0V_0^{\gamma} = P_1V_1^{\gamma} \therefore P_0 = P_1 \left(\frac{V_1}{V_0}\right)^{\gamma}$

$$P_0 = 1 \times \left(\frac{20}{10}\right)^{1{,}4} = 2^{1{,}4} = 2{,}64\,atm$$ $P_0 = 2{,}64\,atm$

$$T_0 = \frac{P_0V_0}{nR} = \frac{2{,}64 \times 10}{1 \times 0{,}082} = 322K$$ $T_0 = 322K$.

Estado (2) $\Rightarrow P_2 = 1atm$ $V_2 = 10L$

$$T_2 = \frac{P_2V_2}{nR} = \frac{1 \times 10}{1 \times 0{,}082} = 122\,K$$

Estados (1) $P_1 = 1atm$, $V_1 = 20L$, $T_1 = 244K$

(2) $P_1 = 1atm$, $V_2 = 10L$, $T_2 = 122K$

(0) $P_0 = 2{,}64atm$, $V_0 = 10L$, $T_0 = 322K$

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Estados
(0) $P_0 = 2{,}64\,atm$, $V_0 = 10L$, $T_0 = 322K$
(1) $P_1 = 1atm$, $V_1 = 20L$, $T_1 = 244K$
(2) $P_2 = 1atm$, $V_2 = 10L$, $T_2 = 122K$

$0 \to 1$: adiabático; $1 \to 2$: isobárico; $2 \to 0$: isocórico

	ΔU (atm.L)	W	Q
$0 \to 1$	−16	16	0
$1 \to 2$	−25	−10	−35
$2 \to 0$	41	0	41

adiabático $\Rightarrow \Delta U = -W$
isobárico $\Rightarrow W = P\Delta V$
isocórico $\Rightarrow \Delta U = Q$

$\Delta U = n c_v \Delta T$ $\qquad \Delta U_{01} = n c_v (T_1 - T_0) = 1 \times \frac{5}{2} \times 0{,}082 (244 - 322)$

$\Delta U_{01} = -16\,atm.L$

$\Delta U_{12} = n c_v (T_2 - T_1) = 1 \times \frac{5}{2} \times 0{,}082 (122 - 244) = -25\,atm.L$

$\Delta U_{20} = n c_v (T_0 - T_2) = 1 \times \frac{5}{2} \times 0{,}082 (322 - 122) = 41\,atm.L$

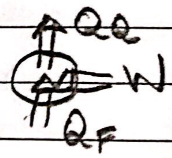
$W_{12} = P_1 \Delta V = P_1 (V_2 - V_1) = 1 \times (10 - 20) = -10\,atm.L$

$\Delta U_{12} = Q_{12} - W_{12} \therefore -25 = Q_{12} + 10 \therefore Q_{12} = -35\,atm.L$

$W_{total} = W_{01} + W_{12} + W_{20} = 16 - 10 + 0 = 6\,atm.L$
Q_Q = calor entrou no ciclo = 41 atm.L

$$e = \frac{W_{total}}{Q_Q} = \frac{6}{41} = 0{,}146 \Rightarrow 14{,}6\%$$

39. Refrigerador $\quad Q_F = 500J$ e $Q_Q = 800J$



$|W| + |Q_F| = |Q_Q|$
$|W| + 500 = 800$
$|W| = 300$

$$e = \frac{|Q_F|}{|W|} = \frac{500}{300} = 1{,}67$$

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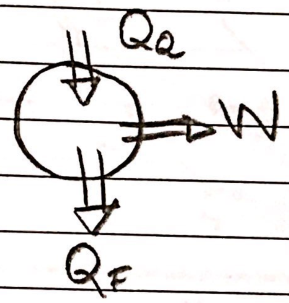
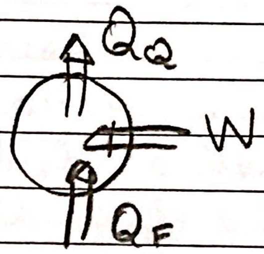
2ª Lei da Termodinâmica





$Q_F \neq 0$ máquina térmica

$W \neq 0$ refrigerador

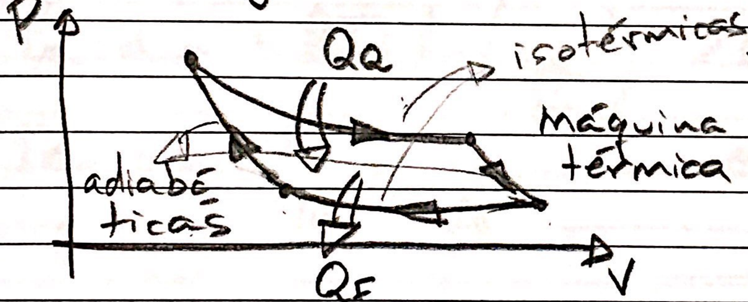
41. Máquina de Carnot $T_Q = 300K$ e $T_F = 200K$

a) e

b) $Q_Q = 100 J$ por ciclo $W = ?$

c) $Q_F = ?$

d) refrigerador coef. desempenho e?



Troca de calor reversível ⇒ isotérmico

Troca de temperatura ⇒ adiabático

expansão isotérmica $W > 0$ $\Delta U = 0 \Rightarrow Q > 0 \Rightarrow Q_Q$

compressão " $W < 0$ $\Delta U = 0 \Rightarrow Q < 0 \Rightarrow Q_F$

$$e = \frac{W}{Q_Q} = \frac{Q_Q - |Q_F|}{Q_Q} = 1 - \left|\frac{Q_F}{Q_Q}\right| \xrightarrow{\text{Carnot}} e = 1 - \frac{T_F}{T_Q}$$

$$e = 1 - \frac{200}{300} = 0{,}33 \Rightarrow 33\% \qquad e = \frac{W}{Q_Q} = 0{,}3333$$

b) $Q_Q = 100 J \Rightarrow W = 33{,}3 J \therefore W = Q_Q - |Q_F| \therefore 33{,}3 = 100 - |Q_F|$

$|Q_F| = 66{,}7 J$ d) $e = \frac{|Q_F|}{W} = \frac{66{,}7}{33{,}3} = 2$

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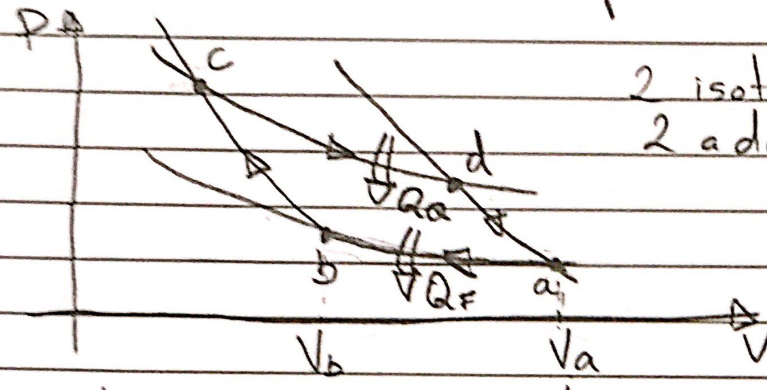
Exercício sobre máquina de Carnot $e = \frac{W}{Q_Q} = 1 - \left|\frac{Q_F}{Q_Q}\right|$



2 isotermicas
2 adiabatica

V_a, P_a e V_b $\quad V_b < V_a$

$T_a = \frac{V_a P_a}{nR} = T_b = T_F$

$a \to b$ compressão isoterma $\Delta U_{ab} = 0 \Rightarrow Q_{ab} = W_{ab}$

$W_{ab} = \int_{V_a}^{V_b} P\,dV = nRT_a \int_{V_a}^{V_b} \frac{1}{V} dV = nRT_a \ln\left(\frac{V_b}{V_a}\right) < 0$

$Q_{ab} = nRT_a \ln\left(\frac{V_b}{V_a}\right) < 0 \qquad Q_F = Q_{ab}$ e $T_a = T_F$

$c \to d$ expansão isotérmica $\Delta U_{cd} = 0 \Rightarrow Q_{cd} = W_{cd}$

$W_{cd} = \int_{V_c}^{V_d} P\,dV = nRT_d \ln\left(\frac{V_d}{V_c}\right) > 0$

$Q_{cd} = nRT_d \ln\left(\frac{V_d}{V_c}\right) > 0 \qquad Q_Q = Q_{cd}$ e $T_d = T_Q$

Temos $\boxed{\frac{V_b}{V_a} = \frac{V_c}{V_d}}$ $\qquad e = 1 - \left|\frac{nRT_F \cancel{\ln\left(\frac{V_b}{V_a}\right)}}{nRT_Q \cancel{\ln\left(\frac{V_d}{V_c}\right)}}\right| = 1 - \frac{T_F}{T_Q}$

$\boxed{e = 1 - \frac{T_F}{T_Q}}$ $\qquad \boxed{e = 1 - \left|\frac{Q_F}{Q_Q}\right|}$

Carnot $\qquad$ outras.

a máquina mais
eficiente $\Rightarrow$ dissipa menos
$\Rightarrow$ processos reverssíveis