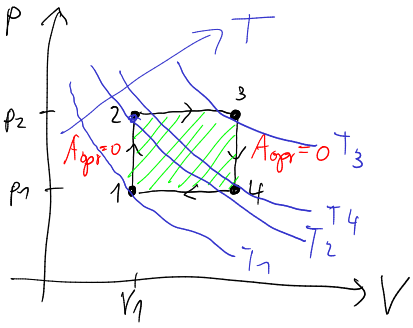
9.43



$p_2 = \lambda p_1 \quad \lambda = 1{,}2$

$V_3 = \mu V_2 \quad \mu = 1{,}4$

$V_1 = V_2$

$V_3 = V_4$

$p_1 = p_4$

$p_2 = p_3$

$T_1 = 27\,^\circ C$

$\kappa = \frac{7}{5} = 1{,}4$

$\eta = ?$

$$\eta = \frac{A_{opr}}{Q_{dov}} = \frac{(p_2 - p_1)(V_3 - V_2)}{m c_V \left[T_2 - T_1 + \kappa (T_3 - T_2)\right]}$$

$$A_{opr} = -A = \int p\,dV$$

$$A_{opr}^{2\to3} = \int_{V_2}^{V_3} p\,dV = p_2 \int_{V_2}^{V_3} dV = p_2 (V_3 - V_2)$$

$$A_{opr}^{4\to1} = \int_{V_4}^{V_1} p\,dV = p_1 (V_1 - V_4) = p_1 (V_2 - V_3)$$

$$\eta = \frac{p_1 (\lambda - 1) V_2 (\mu - 1)}{\frac{m R}{M(\kappa - 1)} \left[T_2 - T_1 + \kappa (T_3 - T_2)\right]} =$$

$$= \frac{p_1 V_1 (\lambda - 1)(\mu - 1)(\kappa - 1)}{p_2 V_2 - p_1 V_1 + \kappa (p_3 V_3 - p_2 V_2)} =$$

$$= \frac{p_1 V_1 (\lambda - 1)(\mu - 1)(\kappa - 1)}{p_1 V_1 \lambda - p_1 V_1 + \kappa (\lambda p_1 \mu V_1 - \lambda p_1 V_1)} =$$

$$= \frac{(\lambda - 1)(\mu - 1)(\kappa - 1)}{\lambda - 1 + \kappa \lambda (\mu - 1)}$$

$$\eta = \frac{0{,}2 \times 0{,}4 \times 0{,}4}{0{,}2 + 1{,}4 \times 1{,}2 \times 0{,}4} = 0{,}037 = 3{,}7\,\%$$

izohorna sprememba:

$Q = m c_V \Delta T$

izobarna sprememba:

$\frac{c_p}{c_V} = \kappa$

$Q = m c_p \Delta T$

$1 \to 2$	$\Delta T = T_2 - T_1 > 0$	plin prejema toploto
$2 \to 3$	$\Delta T = T_3 - T_2 > 0$	
$3 \to 4$	$\Delta T = T_4 - T_3 < 0$	oddaja
$4 \to 1$	$\Delta T = T_1 - T_4 < 0$	

$Q_{dov} = Q^{1\to2} + Q^{2\to3} =$

$= m c_V (T_2 - T_1) + m c_p (T_3 - T_2)$

$\frac{c_p}{c_V} = \kappa \qquad c_p = c_V + \frac{R}{M}$

$c_V = \frac{R}{M(\kappa - 1)}$

$pV = \frac{m}{M} R T$

9.22

$m_v = 0{,}9\ kg$
$m_l = 0{,}1\ kg$
$T_0 = 0°C$
$m_{Al} = 1\ kg$
$T_{Al} = 200°C$

$c_{Al} = 900\ J/kgK$
$c_v = 4180\ J/kgK$
$\varrho_t = 336\ kJ/kg$

$T = ?$
$\Delta S = ?$

1. stali amo del ledu (v ten prostoru je $T = T_0$)

$Q_{odd}^{Al} = Q_{pr}^{v+l} = Q_{pr}^{l}$ → masa ledu, ki se je stalil

$m_{Al} c_{Al} (T_{Al} - T_0) = m_l^s \varrho_t$

$m_l^s = \frac{m_{Al} c_{Al} (T_{Al} - T_0)}{\varrho_t} = \frac{1\,kg \cdot 900\,J/kgK \cdot 200\,K}{336000\,J/kg} = \frac{180}{336}\,kg = 0{,}53\,kg$

2. stali se ves led

$Q^{Al} = Q_{pr}^{v+l}$

$m_{Al} c_{Al} (T_{Al} - T) = m_l \varrho_t + (m_v + m_l) c_v (T - T_0)$

$m_{Al} c_{Al} (T_{Al} - T_0 - (T - T_0)) = m_l \varrho_t + (m_v + m_l) c_v (T - T_0)$

$-T_0 + T_0$

$T - T_0 = \frac{m_{Al} c_{Al} (T_{Al} - T_0) - m_l \varrho_t}{m_{Al} c_{Al} + (m_v + m_l) c_v}$

$T - T_0 = \frac{1\,kg \cdot 900\,J/kgK \cdot 200\,K - 0{,}1\,kg \cdot 336000\,J/kg}{1\,kg \cdot 900\,J/kgK + 1\,kg \cdot 4180\,J/kgK}$

$T - T_0 = \frac{900 \cdot 200 - 0{,}1 \cdot 336000}{900 + 4180}\,K = 28{,}8\,K$

$T = T_0 + 28{,}8\,K = 28{,}8\,°C$

$dS = \frac{dQ}{T}$ ← pri reverzibilni spremembi
← v K

$\Delta S = \Delta S_{Al} + \Delta S_{v+l} =$

$= \int_{T_{Al}}^{T} dS_{Al} + \int_{?}^{T} dS_v + \frac{m_l \varrho_t}{T_0} =$

$= \int_{T_{Al}}^{T} \frac{m_{Al} c_{Al} dT}{T} + \int_{?}^{T} \frac{(m_l + m_v) c_v dT}{T} + \frac{m_l \varrho_t}{T_0} =$

$= m_{Al} c_{Al} \ln \frac{T}{T_{Al}} + (m_l + m_v) c_v \ln \frac{T}{T_0} + \frac{m_l \varrho_t}{T_0} =$

$= 1\,kg \cdot 900\,J/kgK \ln \frac{301{,}8\,K}{473\,K} + 1\,kg\ 4180\,J/kgK \ln \frac{301{,}8\,K}{273\,K} + \frac{0{,}1\,kg \cdot 336000\,J/kg}{273\,K} =$

< 0 > 0

$= 138 \ J/K$

9.49

$\phi_m = \frac{1\,kg}{10\,min}$

$T_1 = 0\,^\circ C$

$T_2 = 30\,^\circ C$

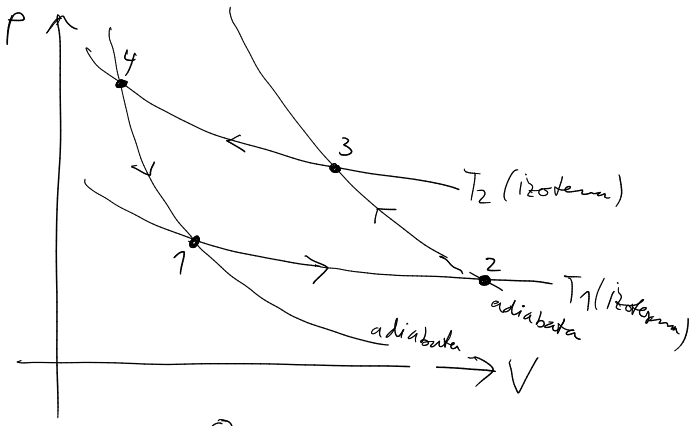
$a = 1\,m$

$d = 5\,cm$

$\lambda_1 = 0{,}1\ W/mK\ ,\ \lambda_2 = 0$

$\varrho_t = 336\ kJ/kg$

$P_1 = ?\ ,\ P_2 = ?$



$\eta = \frac{Q_{pr}}{A_{pr}} \rightarrow Q_{pr} = \eta A_{pr}$

$Q_{pr} = m_t \varrho_t + Q_{iz\ stolice}$

$\eta A_{pr} = m_t \varrho_t + Q_{iz\ stolice} \ /\ \frac{d}{dt}$

$\eta P = \phi_m \varrho_t + P_{iz\ stolice}$

↖ toplotni tok, ki teče skozi steno hladilnika

$P_{iz\ stolice} \doteq S \cdot \lambda \cdot \frac{\Delta T}{d} \qquad \Delta T = T_2 - T_1$

↖ površina stene: $S = 6a^2$

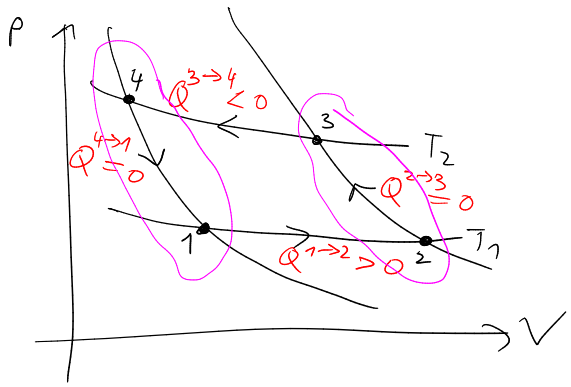
$\eta P = \phi_m \varrho_t + 6a^2 \lambda \frac{(T_2 - T_1)}{d}$

$P = \frac{\phi_m \varrho_t + 6a^2 \lambda \frac{T_2 - T_1}{d}}{\eta}$

$\eta = ?$

$\eta = \frac{Q_{pr}}{A_{pr}}$

$\eta = \frac{Q^{1\to 2}}{A^{1\to 2} + A^{2\to 3} + A^{3\to 4} + A^{4\to 1}}$



izotermna spremenba: ($\Delta T = 0$) $\quad \Delta W_n = A + Q$

$m c_v \Delta T = 0 = A + Q \rightarrow Q = -A = \int p\,dV$

$A = -\int p\,dV$

adiabatna spremenba: ($Q = 0$) $\quad \Delta W_n = A + Q$

$\Delta W_n = A \longrightarrow A = m c_v \Delta T$

$$\eta = \frac{\int_{1\to 2} p\,dV}{-\int_{1\to 2} p\,dV + m c_v (T_2 - T_1) - \int_{3\to 4} p\,dV + m c_v (T_1 - T_2)} = -\frac{1}{1 + \frac{\int_{3\to 4} p\,dV}{\int_{1\to 2} p\,dV}}$$

$p' = \frac{m}{n} R T \rightarrow p = \frac{m R T}{n V}$ (= konst)

$$\eta = -\frac{1}{1 + \frac{\frac{m}{n} R T_2 \int_{V_3}^{V_4} \frac{dV}{V}}{\frac{m}{n} R T_1 \int_{V_1}^{V_2} \frac{dV}{V}}} = -\frac{1}{1 + \frac{T_2}{T_1} \frac{\ln(V_4/V_3)}{\ln(V_2/V_1)}} = -\frac{1}{1 - \frac{T_2}{T_1}} = \frac{1}{\frac{T_2}{T_1} - 1}$$

↑

adiabata: $pV^k = konst.$

$: \frac{pV}{T} = konst.$

$V^{k-1} T = konst.$

$V_1^{k-1} T_1 = V_4^{k-1} T_2$

$V_2^{k-1} T_1 = V_3^{k-1} T_2$:

$\left(\frac{V_1}{V_2}\right)^{k-1} = \left(\frac{V_4}{V_3}\right)^{k-1} \rightarrow \frac{V_1}{V_2} = \frac{V_4}{V_3}$

$\rightarrow \ln \frac{V_4}{V_3} = \ln \frac{V_1}{V_2} = -\ln \frac{V_2}{V_1}$

$\eta = \frac{1}{\frac{T_2}{T_1} - 1} = \frac{1}{\frac{303K}{273K} - 1} = 9,1$

$P_1 = \left(\phi \cdot \eta \varrho_t + 6a^2 \lambda \frac{T_2 - T_1}{d}\right)\left(\frac{T_2}{T_1} - 1\right) =$

$P_2 : 0,1 \rightarrow 0$

$W = \frac{J}{s}$

$= \left(\frac{1kg}{600s} \cdot \frac{336000J}{kg} + 6 W/m^2 \cdot \frac{0,1 W}{mK} \cdot \frac{30K}{0,05m}\right)\left(\frac{303K}{273K} - 1\right) =$

$= 101,1\ W$

$P_2 = 61,5\ W$

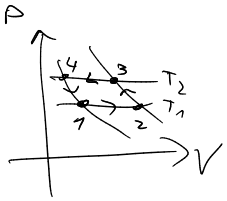
- če snov, ki opravlja krožno spremembo ni idealni plin

$1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1 : \Delta W = A + Q$

$0 = A + Q$

$0 = A + Q^{1\rightarrow 2} + Q^{3\rightarrow 4}$

$\Delta S = \frac{Q^{1\rightarrow 2}}{T_1} + \frac{Q^{3\rightarrow 4}}{T_2} = 0$



$\eta = \frac{Q_{pr}}{A} = \frac{Q^{1\rightarrow 2}}{-Q^{1\rightarrow 2} - Q^{3\rightarrow 4}} =$

$\frac{Q^{3\rightarrow 4}}{Q^{1\rightarrow 2}} = -\frac{T_2}{T_1}$

$\eta = -\frac{1}{1 + \frac{Q^{3\rightarrow 4}}{Q^{1\rightarrow 2}}} = \frac{1}{1 - \frac{T_2}{T_1}} = \frac{1}{\frac{T_2}{T_1} - 1}$