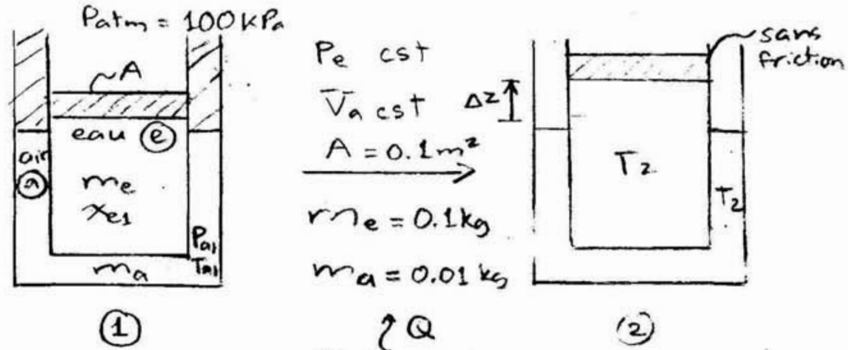
MEC1210 Automne 2024, TD4, Groupe 2: Problème à faire en classe (solutionnaire)



$x_{e1} = 0.5$

$T_{a1} = 27°C$

$P_{a1} = 101\ kPa$

$T_{rés} = 150°C$ (gaz chauds)

équilibre thermique avec rés.

$T_2 = T_{rés} = 150°C$

- $M_{piston} \simeq 0$
- air → gaz parfait avec C_p, C_v const, $R = 0.287\ \frac{kJ}{kg \cdot K}$, $C_p = 1.005$
- $\Delta U_{paroi, piston, gaz\ chauds} \simeq 0$
- $\Delta S_{paroi, piston, gaz\ chauds} \simeq 0$
- Isolants parfaits ($Q_{out} = 0$)
- $\Delta E_c, \Delta E_p \simeq 0$
- évolution quasi-statique

a) $\Delta z = ?$

b) $Q = ?$

c) $S_{gen} = ?$

d) diagramme T-s pour air et eau

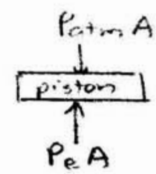
Suppositions additionnelles

(aucune)

a) $\Delta z = ?$: $A\Delta z = V_{e2} - V_{e1} = m_e(v_{e2} - v_{e1})$

$$\Delta z = \frac{m_e}{A}(v_{e2} - v_{e1})$$

⇒ $v_{e1} = ?$: $P_{e1} = ?$:



$\Sigma F_z = P_e A - P_{atm} A = 0$ (quasi-statique)

$P_e = P_{atm} = $ const,

$P_{e1} = P_{e2} = P_{atm} = 100\ kPa$

$\left.\begin{array}{l} P_{e1} = 100\ kPa \\ x_{e1} = 0.5 \end{array}\right\}$ mélange sat.

Table A-5 : ($P_{sat} = 100\ kPa$) $v_f = 0.001043\ \frac{m^3}{kg}$, $v_g = 1.6941\ \frac{m^3}{kg}$

$\left(\begin{array}{ll} u_f = 417.40\ \frac{kJ}{kg} & s_f = 1.3028\ \frac{kJ}{kg \cdot K} \\ u_{fg} = 2088.2 & s_{fg} = 6.0562 \end{array}\right)$

$v_{e1} = v_f + x_{e1}(v_g - v_f) = 0.8476\ m^3/kg$

$\left(\begin{array}{l} u_{e1} = u_f + x_{e1} u_{fg} = 1461.5\ \frac{kJ}{kg} \\ s_{e1} = s_f + x_{e1} s_{fg} = 4.3309\ \frac{kJ}{kg \cdot K} \end{array}\right)$

$$\Rightarrow v_{e2} = ? : \quad \left. \begin{array}{l} P_{e2} = P_{e1} = 100 \text{ kPa} \\ T_{e2} = T_2 = 150°C \end{array} \right\} \begin{array}{l} T_{e2} > T_{sat@100kPa} \\ \text{vap. sur.} \end{array}$$

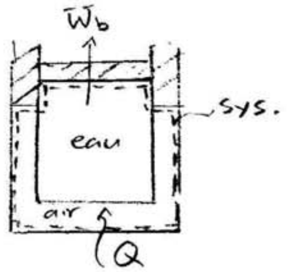
Table A-6 : $v_{e2} = 1{,}9367 \ m^3/kg$

$$\begin{pmatrix} u_{e2} = 2582{,}9 \ kJ/kg \\ s_{e2} = 7{,}6148 \ kJ/kg \cdot K \end{pmatrix}$$

$$\Delta z = \frac{(0.1 \ kg)}{(0.1 \ m^2)} (1{,}9367 - 0{,}8476) \frac{m^3}{kg}$$

$$\boxed{\Delta z = 1.0891 \ m}$$

b) $Q = ?$:



bilan d'énergie : $\Delta E_{sys} = E_{in} - E_{out}$ (1ère loi)

$$\Delta U_{eau} + \Delta U_{air} + \cancel{\Delta U_{paroi}}^{\cong 0} + \cancel{\Delta E_c}^{\cong 0} + \cancel{\Delta E_p}^{\cong 0} = Q - W_b$$

$$m_e(u_{e2} - u_{e1}) + m_a(u_{a2} - u_{a1}) = Q - \int_1^2 P_e dV$$

$$m_e(u_{e2} - u_{e1}) + m_a c_{va}(T_2 - T_{a1}) = Q - P_{e1} m_e (v_{e2} - v_{e1})$$

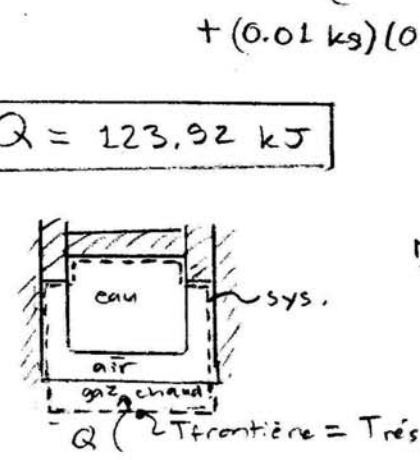
$$Q = m_e \left[u_{e2} - u_{e1} + P_e (v_{e2} - v_{e1}) \right] + m_a c_{va} (T_2 - T_{a1})$$

$$\Rightarrow c_{va} = c_{pa} - R = 1{,}005 - 0.287 = 0{,}722 \ \frac{kJ}{kg \cdot K}$$

$$= (0.1 \ kg) \left[(2582{,}9 - 1461{,}5) \frac{kJ}{kg} + (100 \ kPa)(1{,}9367 - 0.8476) \frac{m^3}{kg} \right] + (0.01 \ kg)(0.722 \ \frac{kJ}{kg \cdot K})(150 - 27)°C \cdot \frac{K}{°C}$$

$$\boxed{Q = 123{,}92 \ kJ}$$

c) $S_{gen} = ?$:



Note : système doit s'étendre en bas jusqu'à ce que $T_{frontière} = T_{rés} = \text{const.}$ pour que S_{gen} inclut irréversibilité due à Q à travers $\Delta T = T_{rés} - T_{air}$

$\underline{\text{bilan d'entropie}}$ (2ème loi) : $\Delta S_{sys} = \int_1^2 \frac{\delta Q}{T} + S_{gen}$

$$\Delta S_{eau} + \Delta S_{air} + \cancel{\Delta S_{\text{parois \& air chauds}}}^{\simeq 0} = \frac{Q}{T_{rés}} + S_{gen}$$

$$m_e(s_{e2} - s_{e1}) + m_a(s_{a2} - s_{a1}) = \frac{Q}{T_{rés}} + S_{gen}$$

$$S_{gen} = m_e(s_{e2} - s_{e1}) + m_a(s_{a2} - s_{a1}) - \frac{Q}{T_{rés}}$$

$$\Rightarrow s_{a2} - s_{a1} = C_{va} \ln \frac{T_2}{T_{a1}} + R \ln \cancel{\frac{v_{a2}}{v_{a1}}}^{1}$$ (gaz parfait avec C_v, C_p const.)

$$= \left(0.722 \frac{kJ}{kg \cdot K}\right) \ln \left(\frac{150 + 273}{27 + 273}\right) + 0$$

$$= 0.2481 \text{ kJ/kg} \cdot \text{K}$$

$\underline{\text{ou}}$

$$s_{a2} - s_{a1} = C_{pa} \ln \frac{T_2}{T_{a1}} - R \ln \frac{P_{a2}}{P_{a1}}$$

$$\Rightarrow \frac{P_{a2}}{P_{a1}} = \frac{\cancel{R} T_2 / \cancel{v_{a2}}}{\cancel{R} T_{a1} / \cancel{v_{a1}}} = \frac{T_2}{T_{a1}}$$

$$s_{a2} - s_{a1} = \underbrace{(C_{pa} - R)}_{C_{va}} \ln \frac{T_2}{T_{a1}} = \text{même qu'avant}$$

$$S_{gen} = (0.1 \text{ kg})(7.6148 - 4.3309) \frac{kJ}{kg} + (0.01 \text{ kg})\left(0.2481 \frac{kJ}{kg \cdot K}\right) - \frac{123.92 \text{ kJ}}{(150 + 273) \text{ K}}$$

$$\boxed{S_{gen} = 0.038 \ \frac{kJ}{K}}$$

d)