Thermodynamics **MCQ Avril 25th 2023**

☐0 ☐0 ☐0 ☐0 ☐0 ☐0 ☐0 ☐0
☐1 ☐1 ☐1 ☐1 ☐1 ☐1 ☐1 ☐1
☐2 ☐2 ☐2 ☐2 ☐2 ☐2 ☐2 ☐2
☐3 ☐3 ☐3 ☐3 ☐3 ☐3 ☐3 ☐3
☐4 ☐4 ☐4 ☐4 ☐4 ☐4 ☐4 ☐4
☐5 ☐5 ☐5 ☐5 ☐5 ☐5 ☐5 ☐5
☐6 ☐6 ☐6 ☐6 ☐6 ☐6 ☐6 ☐6
☐7 ☐7 ☐7 ☐7 ☐7 ☐7 ☐7 ☐7
☐8 ☐8 ☐8 ☐8 ☐8 ☐8 ☐8 ☐8
☐9 ☐9 ☐9 ☐9 ☐9 ☐9 ☐9 ☐9

⟵ Please enter you student number, and write your name above.

NAME, First Name :

....

Duration : 30 minutes - No document allowed and all calculators authorised - No wifi no 4/5G

Q1 A closed system has ten moles of an ideal gas of molar specific heat capacities $\overline{C}_{V_m} = 20.8\,\mathrm{J/(mol\ K)}$ and $\overline{C}_{P_m} = 29.1\,\mathrm{J/(mol\ K)}$. It is compressed in an adiabatic and reversible way from an initial pressure $P_i = 7\,\mathrm{bar}$ to a final $P_f = 49\,\mathrm{bar}$. Knowing that the initial system volume is $V_i = 20\,\mathrm{L}$, give and demonstrate the literal expression of the final temperature T_f as function of the given data.

Reminder : $R = 8.314\,\mathrm{J/(mol\ K)}$, $1\,\mathrm{bar} = 10^5\mathrm{Pa}$, $0\,°\mathrm{C} = 273\,\mathrm{K}$. ☐Empty ☐0 ☐1 ☐2 ☐3 ■4

In a reversible adiabatic process, the relationship $PV^\gamma = const$ with $\gamma = \overline{C}_{P_m}/\overline{C}_{V_m}$ applies leading to $V_f = V_i\left(\frac{P_i}{P_f}\right)^{1/\gamma}$. Then, by applying the ideal gas law in the final state, we get $T_f = \frac{P_f V_f}{nR}$ leading to : $T_f = \frac{P_f V_i \left(\frac{P_i}{P_f}\right)^{(\overline{C}_{V_m}/\overline{C}_{P_m})}}{nR}$ (4 pts)

Q2 Give the numerical value of the final temperature T_f in K.

☐0 ☐1 ■2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9
☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ■9
☐0 ☐1 ☐2 ■3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9

Q3 For open systems in adiabatic steady state flow processes, we have :

☐ $\Delta_s\dot{H} + \Delta_s\dot{E}_k^M + \Delta_s\dot{E}_p^M = \dot{Q} + \dot{W}_s$ ■ $\dot{Q} = 0$ ☐ $\Delta_s\dot{H} + \Delta_s\dot{E}_k^M + \Delta_s\dot{E}_p^M = \dot{Q} + \dot{W}_{pf} + \dot{W}_s$
☐ $\Delta_s\dot{U} = \dot{Q} + \dot{W}_s$ ■ $\dot{W}_{pf} = 0$

Q4 An ideal gas (closed system of n moles in a volume V with specific molar heat capacities $\overline{C}_{V_m}$ and $\overline{C}_{P_m}$) undergoes an isochoric process from P_i, T_i to P_f, T_f. We have :

☐ $Q = n\overline{C}_{V_m}\Delta_t T$ ☐ $\Delta_t H = n\overline{C}_{V_m}\Delta_t T$ ☐ $\Delta_t U = Q + W_{pf} + W_s$ ■ $\Delta_t U = n\overline{C}_{V_m}\Delta_t T$
☐ $W_{pf} = -P\Delta V$

Q5 A closed system with 0.86 kg of only liquid water at $T_i = 100\,°\text{C}$ and $P_i = 1.0\,\text{atm}$ is first heated isobarically to entirely vaporise the water and then isochorically compressed to $P_f = 7.8\,\text{atm}$. Give and demonstrate the literal expression of the heat exchanged during the entire process. Reminder : water latent heat : $L_{vap_w} = 2256\,\text{kJ/kg}$
Water mass specific heat capacities : $\overline{C}_{\text{water}} = 4.184\,\text{kJ/kg K}$, $\overline{C}_{V_{\text{steam}}} = 1.405\,\text{kJ/kg K}$, $\overline{C}_{P_{\text{steam}}} = 1.867\,\text{kJ/kg K}$
Data : $M_w = 18\,\text{g/mol}$, $R = 8.314\,\text{J/(mol K)}$, $1\,\text{atm} = 101\,325\,\text{Pa}$, $0\,°\text{C} = 273\,\text{K}$,

☐Empty ☐0 ☐1 ☐2 ☐3 ■4

The entire process can be divided in two intermediate ones ($1 \to int$ and $int \to 2$) : the first with the isobaric water vaporisation and the second with the isochoric steam compression. For the first, $Q_1 = m_w L_{vap_w}$ whereas for the second $Q_2 = m_w \overline{C}_{V_w}(T_f - T_i)$ with $T_f = P_f V_f M_w / m_w R$ (ideal gas law) knowing that $V_f = V_{int} = \frac{m_w R T_i}{M_w P_i}$. So : $Q = m_w L_{vap_w} + m_w \overline{C}_{V_w}(\frac{P_f T_i}{P_i} - T_i)$ (4 pts)

Q6 Give the numerical value of Q in MJ.

	☐0 ☐1 ☐2 ☐3 ☐4 ■5 ☐6 ☐7 ☐8 ☐9
	.
■+	■0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9
☐−	■0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9

Q7 A turbine of a hydroelectric powerplant receives a constant flow rate ($\dot{V}_w = 34\,\text{m}^3/\text{min}$) of liquid water from a dam (altitude $h_{in} = 1083\,\text{m}$, pressure $P_{in} = 4.5\,\text{atm}$) and gives out the same flow rate to the downward valley (altitude $h_{out} = 513\,\text{m}$, pressure $P_{out} = 1.0\,\text{atm}$). Assuming an adiabatic reversible process, give and demonstrate the literal equation of the turbine shaft work $\dot{W}_s$ as function of the given data.
The liquid water density is $\rho_w = 10^3\,\text{kg/m}^3$, $g = 9.81\,\text{m/s}^2$ and $1\,\text{atm} = 101\,325\,\text{Pa}$.

☐Empty ☐0 ☐1 ☐2 ☐3 ■4

For open systems in steady-state conditions, the first law is $\Delta_s \dot{H} + \Delta_s \dot{E}_k^M + \Delta_s \dot{E}_p^M = \dot{Q} + \dot{W}_s$. In this case, $\Delta_s \dot{E}_k^M = 0$ (static system), $\Delta_s \dot{E}_p^M = \rho_w \dot{V}_w g(h_{out} - h_{in})$ and, for reversible adiabatic ($\dot{Q} = 0$) processes of liquids, $\Delta_s \dot{H} = \int_{in}^{out} \dot{V}_w dP = \dot{V}_w(P_{out} - P_{in})$ leading to : $\dot{W}_s = \dot{V}_w(P_{out} - P_{in}) + \rho_w \dot{V}_w g(h_{out} - h_{in})$. (4 pts)

Q8 Give the numerical value of the shaft work $\dot{W}_s$ in MW.

	☐0 ☐1 ☐2 ■3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9
	.
☐+	☐0 ☐1 ☐2 ■3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9
■−	☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ■7 ☐8 ☐9