NAME:.. FIRSTNAME:.. GROUP:.........

Physics Final Exam n° 2

Calculators and extra-documents are not allowed.

Answer only on the exam sheets.

MCQ (4 points ; no negative points)

1- The differential of the internal energy dU of a gas is given by the first principle and reads:

a) $dU = -PdV + Q$ b) $dU = -PdV + \delta Q$ c) $\delta U = -PdV + \delta Q$

2- The transformation of an ideal gas from state (1) to state (2) is an adiabatic one. Its volume V_2 satisfies:

a) $V_2 = V_1.\left(\frac{P_2}{P_1}\right)^{1/\gamma}$ b) $V_2 = V_1.\left(\frac{P_1}{P_2}\right)^{1/\gamma}$ c) $V_2 = V_1.\left(\frac{P_2}{P_1}\right)^{-\gamma}$ d) $V_2 = \gamma.V_1$

γ is the Laplace coefficient.

3- We are considering an isothermal transformation of a closed system, here an ideal gas. The amount of exchanged heat with the surrounding medium is:

a) $Q = W$ *b)* $Q = \Delta U$ *c)* $Q = -W$ *d)* $Q = 0$

4- During an isothermal transformation of temperature T from state (1) to state (2), the work of the pressure forces is:

a) $W = -n.R.T\ln\left(\frac{V_2}{V_1}\right)$ b) $W = -nRT(V_2 - V_1)$ c) $W = n.R.T\ln\left(\frac{V_2}{V_1}\right)$ d) null

5- During an adiabatic transformation of n moles of an ideal gas, whose molar heat capacity is c_v, from state (1) to state (2), the work of the pressure forces is:

a) $W = -n.R.T\ln\left(\frac{V_2}{V_1}\right)$ b) $W = P_2.V_2^{\gamma} - P_1.V_1^{\gamma}$ c) $W = n.c_v(T_2 - T_1)$

6- Which quantity is not a state function?

a) The enthalpy H b) The internal energy U c) The work of the pressure forces W

7- For an isobaric transformation from state (1) to state (2), the temperature and the volume of an ideal gas satisfy:

a) $T_1.V_2 = T_2V_1$ b) $T_1.V_1 = T_2V_2$ c) $\frac{V_1}{T_2} = \frac{T_1}{V_2}$

8- The Laplace law can be written in terms of the temperature and the pressure, and it reads:

a) $T.P^{\gamma-1} = C$ b) $T^{\gamma}.P^{\gamma-1} = C$ c) $T.P^{\gamma+1} = C$ d) $T^{\gamma}.P^{1-\gamma} = C$

(''C'' is a constant)

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Exercise 1 **The questions 1 and 2 are independent** (4 points)

1- In a calorimeter 10g of water vapor at 100°C are injected on 50 g of iced water at 0°C. Compute the equilibrium temperature. Are given:

Heat capacity per mass unit of liquid water: $C_w = 4.10^3$ $J.kg^{-1}.K^{-1}$

Latent fusion heat of ice $L_f = 3.10^5$ $J.kg^{-1}$

Latent vaporization heat $L_v = 2.10^6$ $J.kg^{-1}$ ($L_{condensation} = - L_{vaporization}$)

2- We are considering a piece of lead of mass m_l=300g initially at temperature θ_l=98°C. This piece of lead is put in a calorimeter, which contains a mass m_2=350g of water. The initial temperature of the system (calorimeter + water) is θ_2=16°C. We measure the equilibrium temperature θ_e=18°C. Compute the heat capacity of the calorimeter. Are given:

Heat capacity per mass unit of water: $c_w = 4.10^3$ $J.kg^{-1}.K^{-1}$

Heat capacity per mass unit of lead: $c_l = 150$ $J.kg^{-1}.K^{-1}$

Exercise 2 **Questions on the lecture** (4 points)

1- We consider an adiabatic transformation. Prove that the differential of the enthalpy dH can be written as $dH = V.dP$

2) a) Recall the expressions of the elementary internal energy dU and the elementary enthalpy dH in terms of the molar heat capacities c_v and c_p of n moles of an ideal gas.

b) Give the expressions of dU and dH in terms of the pressure and the volume for an adiabatic transformation.

c) Deduce the expression of Laplace's law.

Exercise 3 *Diesel's ideal cycle* (8 points)

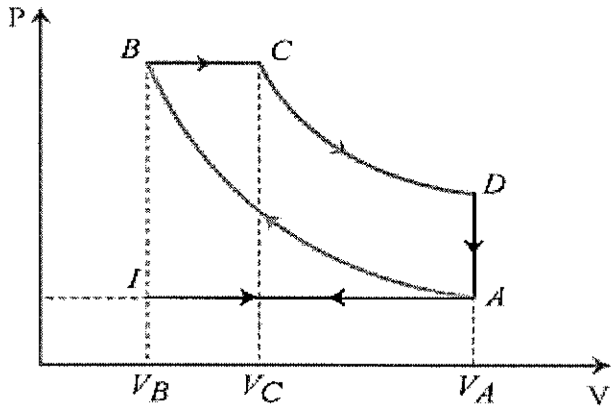
Diesel's engine is an internal combustion engine, whose combustion is due to high compression. Air and fuel are compressed separately. The work of this engine can be described by the following cycle: two adiabatic transformations, one isochoric and one isobaric.

More precisely, it can be described by the following transformations:

- First, air is injected in a cylinder of volume V_A (step IA of the cycle). The valves are closed.
- Then the air is adiabatically compressed (step AB).
- The injection of fuel starts at point B and stops at point C. This injection occurs at constant pressure (step BC).
- The valves are still closed. The combustion products adiabatically relax by pushing the piston back to its initial position (step CD).
- The valves open: the pressure quickly drops (portion DA) and the burnt gases are released.

The cycle is characterized by the compression ratio $\alpha = \frac{V_A}{V_B}$ and the relaxation ratio $\beta = \frac{V_C}{V_B}$.

We assume in this exercise that the system (air/fuel) is an ideal fluid.



1- a) Use the Laplace law to recover the expressions

$$T_A . V_A^{\gamma-1} = T_B . V_B^{\gamma-1} \text{ and } T_C . V_C^{\gamma-1} = T_D . V_D^{\gamma-1}$$ (γ is the Laplace coefficient).

b) Use the property of the isobaric transformation BC to prove the relation: $\frac{T_C}{V_C} = \frac{T_B}{V_B}$

c) Deduce from questions a) and b) the following relations:

$T_C = \beta . T_B \qquad T_A = (\alpha)^{1-\gamma} . T_B \qquad T_D = \beta^{\gamma}(\alpha)^{1-\gamma} . T_B$

2- Determine the amount of heat Q, the work of the pressure forces W and the variations of the internal energy ΔU for the four transformations of the cycle. We are studying *n* moles of an ideal gas. **Give the expressions in terms of the temperatures.**

3- a) Deduce the engine efficiency, which is given by: $r = \frac{Q_{BC}+Q_{DA}}{Q_{BC}}$.
The efficient must be expressed in terms of α, β and γ. Use the relations found in the question 1-c).

b) Compute numerically r for $\alpha = 14$, $\beta = 1{,}6$ and $\gamma = 1{,}4$. Are given: $14^{0{,}4} \approx 3$ and $1{,}6^{1{,}4} \approx 2$