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

# Physics final exam n°2

*Calculators and extra-documents are not allowed.*
***Please answer on exam sheets***

## *Exercise 1* (5 points) ***Parts 1 and 2 are independent.***

**1-** A calorimeter of neglected heat capacity is containing a mass $m_1 = 200g$ of water at initial temperature $\theta_1 = 70°C$. One puts an ice cube of mass $m_2 = 80g$ which was in a fridge at temperature $\theta_2 = -20°C$.
Express the amount of heat Q which is exchanged by water and ice cube. Deduce from it the equilibrium temperature $\theta_e$. We assume that the whole ice cube melts.
Data: Fusion latent heat of ice: $L_f = 300.10^3 Jkg^{-1}$.
Heat capacity of water per mass unit: $c_w = 4.10^3 JK^{-1}kg^{-1}$.
Heat capacity of ice per mass unit: $c_i = 2.10^3 JK^{-1}kg^{-1}$.

**2-** A calorimeter is containing a mass $m_1$ = 150g of water. The initial temperature of the entire system is $\theta_1$=20°C. One adds a mass $m_2$= 250g of water at temperature $\theta_2$=70°C.
Compute the heat capacity $C_{cal}$ of calorimeter. One assumes that the equilibrium temperature is $\theta_e$=50°C. The heat capacity of water per mass unit is given: $c_w = 4.10^3 JK^{-1}kg^{-1}$.

## Exercise 2

(7 points) ***Questions 1, 2 and 3 are independent.***

**1-** a) Write the elementary energy dU and the elementary enthalpy dH of an ideal gas.
b) Deduce from it the Meyer's relation which reads: $C_p - C_V = nR$ and is true for an ideal gas.

**2-** a) Write the first principle of thermodynamics which expresses dU in terms of the elementary quantities $\delta Q$ et $\delta W$.

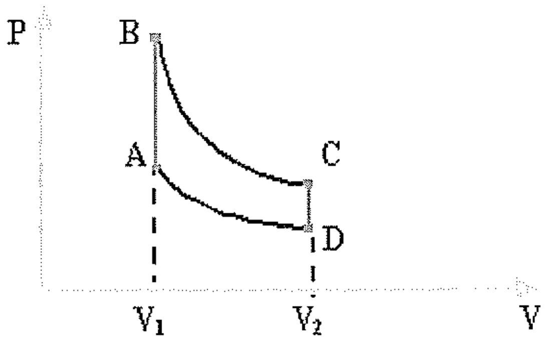
b) Use this principle and Meyer's relation for an ideal gas to prove that the elementary exchanged heat for n moles of ideal gas at constant pressure reads: $\delta Q_p = n.c_p.dT$. (If pressure is constant one has $dV/V = dT/T$).

**3-** Write the work W of pressure forces for the following cases:

a) Isobaric relaxation at pressure $P_A$ from volume $V_A$ to volume $V_B$.
b) Adiabatic compression from volume $V_A$ to volume $V_B$ in terms of temperatures $T_A$, $T_B$ and the molar heat capacity at constant volume $c_v$.

## *Exercise 3* (8 points)

A thermal engine works by following the so-called Beau de Rochas' cycle: n moles of ideal gas is following the cycle **ABCDA** which is sketched below.




The transformations DA and BC are adiabatic whereas the transformations CD and AB isochoric. Oen defines **a** $=\mathbf{V_2 / V_1}$ the ratio between volumes (called the compression rate). Remember that the molar capacity $\mathbf{c_V}$ is constant during this cycle.

**1-** Use Laplace's law to prove the following relations:

$$T_B(V_1)^{\gamma-1} = T_C(V_2)^{\gamma-1}$$
$$T_A(V_1)^{\gamma-1} = T_D(V_2)^{\gamma-1}$$

**2**- Write the amount of heat Q, the work W and the variation of internal energy ΔU for each cycle transformation in terms of temperatures.

**3-** a) Express the efficiency of this engine defined as $r = \dfrac{Q_{AB} + Q_{CD}}{Q_{AB}}$ in terms of temperatures.

b) Recover an expression of this efficiency in terms of **a** and **γ (a =V₂ / V₁)**.

Hint: $\dfrac{T_C - T_D}{T_B - T_A} = \dfrac{T_D}{T_A} = \dfrac{T_C}{T_B}$

c) Compute numerically with **a = 9** and **γ = 1,4.** One gives: $9^{-0,4} \approx 0,4$