FINAL Exam ***Autumn 2018***

Duration: **90** minutes

- It is advisable to take knowledge of the entire text before answering any question.

- Applicants must respect the used notation and specify in each case the question number.

- Most attention will be given to the clarity of writing, presentation, the diagram and the presence of measurement unit

Results will be put in frames

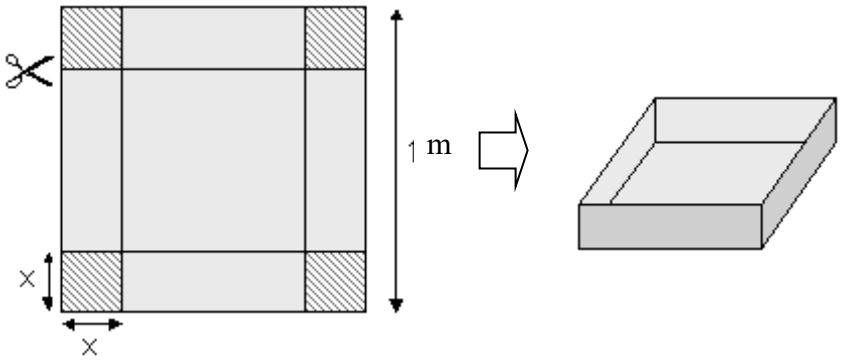
Exercises are independent

Documentation: An A4 double face is authorized, Calculator authorized, phone forbidden

Exercise 1:

A car manufacturer wants to realize an electrical vehicle. The battery pack should be incorporated under the chassis and put inside a metallic box (having a square shape with no cover). In order to built this metallic box, the manufacturer has a square metallic plate of 100cm on each side, he cuts on each corner small squares of x centimeters side. By doing this cut, he can obtain the requested metallic box as shown in the figure below.

We recall that $1cm^3=10^{-3}$ liter



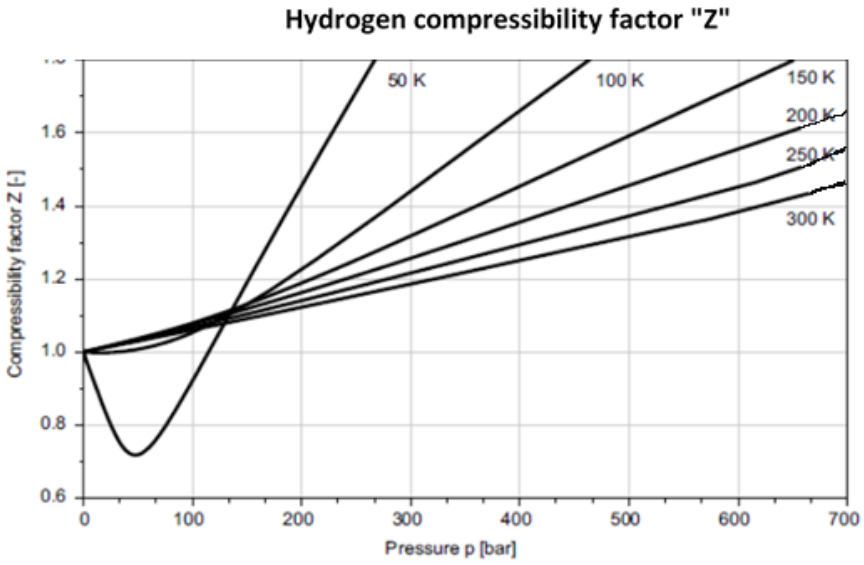
1) Give the set of admissible values of x (in cm)
2) Give the equation of the obtained box volume V(x) as function of x
3) We want to maximize this volume, which value of x (called x*) maximize V(x).
4) Calculate this maximal volume V(x*) in liter
The embedded batteries are Lithium type having the energy volume density of 400 Wh/l.
5) Which quantity of energy that can this box contain if we take the maximum box volume.
6) If we consider that this electrical vehicle consumes a constant power of 6 kW, which autonomy it can have in hour.

Exercise 2:

The TOYOTA Mirai is a fuel cell car with an equivalent fuel consumption of 3.5 liters of SP95-E10 by 100 km and a 500 km range according to the WLTP (Worldwide harmonized Light vehicles Test Procedure) and pursuant to SAE J2601 standards.

The average speed according to the WLTP cycle is around 40 km/h
The conditions for the SAE J2601: 20°C ambient temperature and 70 MPa fuelled hydrogen normal tank pressure
Power of the electric motor: 114 kW
Very performant drag coefficient in the air SC_X =0.29 m²
Total mass of the loaded car: m=1850 kg

Lower Calorific Power of Hydrogen: 33.33 kWh/kg
Lower Calorific Power of SP95-E10: 9.46 kWh/l
Molar mass of H_2 = 2.016 g. mol^{-1}
R = 8.314 $J.mol^{-1}.K^{-1}$
[J]=[$Pa.m^3$]
Volumic mass of the air: ρ=1.3 $kg.m^{-3}$
Gravitational Acceleration: g=9.81 $m.s^{-2}$; 0°C=273,15 K ; 1 bar = 10^5 Pa.



1. What is the equivalent of unleaded petrol capacity in liters of the tank to ensure the expected range?
2. What is the equivalent amount of hydrogen in kg?
3. What is the approximate capacity in litres of water of the hydrogen fuel tank of the TOYOTA Mirai at 70 MPa and 20 °C to store this mass knowing the compressibility value "z" function of temperature and pressure?
4. What is the mean power of the vehicle on the WLTP cycle?
5. The penetration force of the MIRAI in the air is given by $F_{air}(V) = \frac{1}{2}\rho S C_X V^2$ in the International System of Units (SI). Calculate the penetration force in the air F_{air} at the mean speed on the WLTP cycle.
6. The force of the rolling resistance of the MIRAI on the road F_R is given by $F_R(V) = mg(12{,}5.10^{-3} + 4{,}2.10^{-4}.V^2)$ in SI units. Calculate the rolling force in the air at the mean speed on the WLTP cycle.
7. What is the corresponding power calculates with the forces of friction on the air and on the road?
8. What can you say about this power?
9. Suppose that the efficiency equal to 1 (P motor=P wheel), calculate the maximum force of the electric motor at 100 km/h.
10. In how many seconds does the MIRAI accelerate from 0 to 100 km/h supposing the acceleration constant and the maximum Force used only to produce the acceleration?