FINAL Exam ***Autumn 2019***

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:

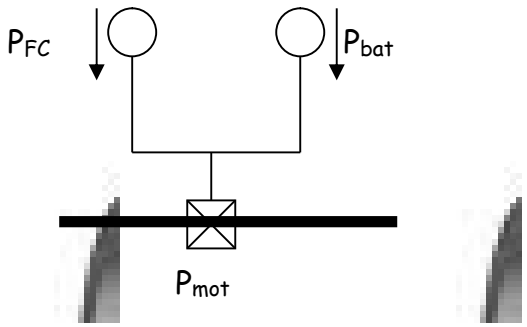
An electrical vehicle has an electric motor consuming an instantaneous power P_{mot}.

To power this motor, we use two sources:

1- A fuel cell giving an instantaneous power P_{FC}
2- A battery delivering an instantaneous power P_{bat}

I) Hybrid sources allow using the advantages of each one of them. The following scenario is adopted:

- If H_2 level is low, the battery will power the motor
- If the battery SOC (state of Charge) is low, the FC will power the motor
- If the motor power demand is high, battery and FC will contribute together to meet the requested power.



The cost function is defined as: $C = \alpha P_{bat}^2 + \beta P_{pile}^2$ where α, β are real parameters.

1) Give the Hamiltonian equation for this system.
2) Determine, as function of P_{mot}, the optimal values of P_{bat} and P_{pile} which minimize the cost function.
3) Give the optimal cost as function of P_{mot}.

II) We admit now, the regenerative braking functioning mode to recharge the battery during braking or if FC produces more power than requested by the motor.

4) Redo, in this case, questions 1), 2) and 3).

Exercise 2: BMW i3 120 Ah

Electric range: 308 km range according to the WLTP (Worldwide harmonized Light vehicles Test Procedure). Technology: Lithium Ion

Total power: 170 HP (125 kW)	Total Motor Torque: 250 N.m	Acceleration: 0 to 100 km/h in 7.3 s
Vehicle Top speed 150 km/h	Battery capacity: 42.2 kWh	Weight: 1423 kg

1. Knowing that the useable battery capacity is 90% of the battery capacity, what is the rated consumption (kWh/100 km) according the WLTP ratings?
2. What is the gasoline equivalent consumption in l/100 km?
3. Lithium battery density is about 184 Wh/kg, what is the mass of the batteries?
4. What's the force that can overcome the vehicle at the top speed?
5. What's then the size of wheel of this car supposing an efficiency of the transmission of 0.85, a direct transmission (ratio=1) and the total torque provided by the motor when the force is maximum?
6. In these conditions of wheel size and direct transmission, what is the motor speed (rpm) at the vehicle top speed?
7. What is the average acceleration value to reach 100 km/h?
8. What is the total force used at the acceleration value?
9. In reality, at witch speed is developed this force?
10. What is the maximum ramp in % that can climb this vehicle at 70 km/h supposing the forces due to rolling and penetration in the air of 600 N?

Lower Calorific Value of gasoline: 12 kWh/kg
Volumic mass of the gasoline: 0.737 kg/l
Volumic mass of the air: ρ=1.3 kg.m-3
Gravitational Acceleration: g=9.81 $m.s^{-2}$