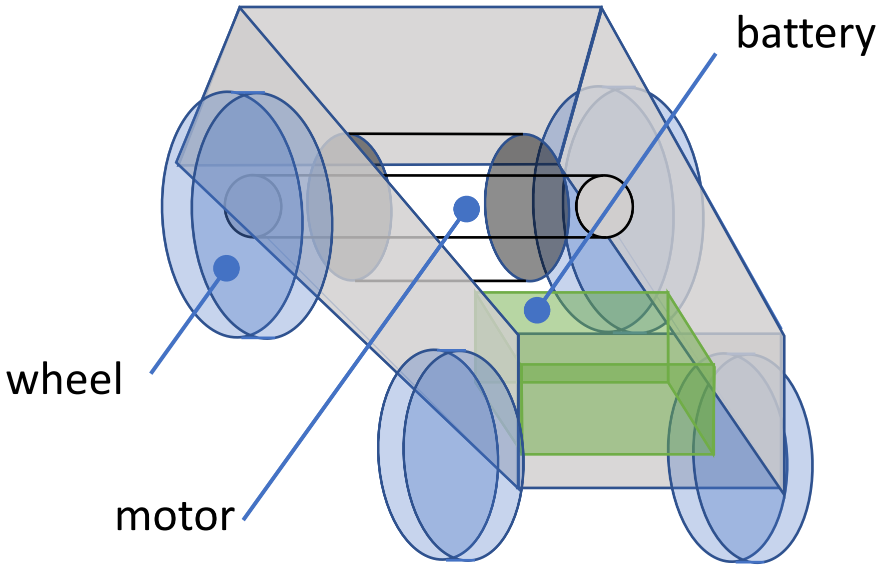
ENS 206 – Spring 2021
Project Assignment

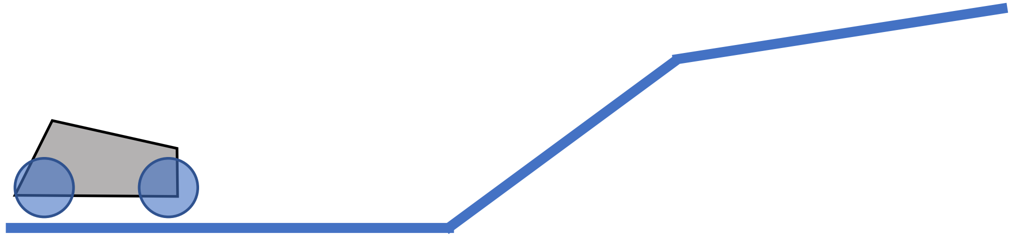
SUMMARY



In this project, you are expected to design a toy race-car, model its dynamics, and simulate its performance along a given parkour.

The toy car to be designed is driven by a DC motor. So, this is an electric car. It runs on a battery compatible to its DC motor. The DC motor is connected to the rear wheel of the car, as shown in the figure.

In order to design the car, you need to:
- Determine the DC motor among certain DC motor models on the web.
- Depending on the motor specs, you will need a compatible battery
- Finally, design the radius of the wheels of the car.

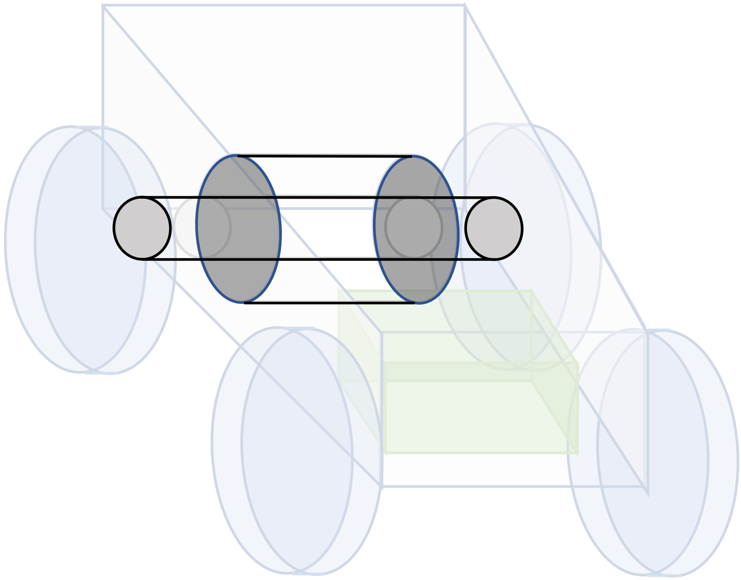


The weight and dynamics of the car will be affected by your choices! Once the design is complete, you expected to simulate the performance of the car along the parkour given in this document.

You have three tasks to complete with your simulation:
1) Try to go as fast as you can. Let's see how agile your design is.
2) Implement a controller that will ensure the velocity of the car is 0.5 m/s throughout the simulation.
3) Compare the performance of two different designs.

DESIGN

There are three elements to complete the design of your car. The first one is the **DC motor**.
Choose a brushed DC motor from the website below based on the specifications of the motor:
https://www.maxongroup.com/maxon/view/catalog?etcc_med=ID+Teaser&etcc_cmp=ID-Teaser-Rebrush-Homepage&etcc_cu=onsite&etcc_var=%5bcom%5d%23en%23_d_&etcc_plc=home



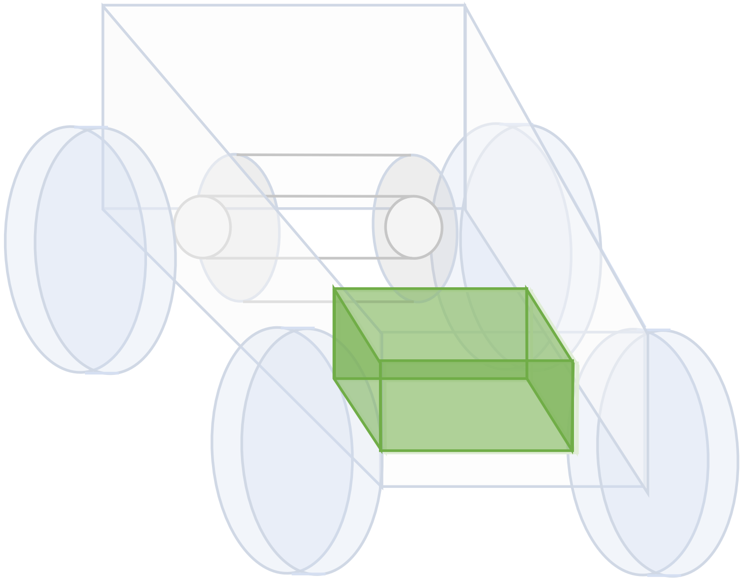
As you know, there were two important parameters that affect the dynamics of a DC motor: torque and speed constants. In addition, you need to account for the weight of the motor, max torque it can provide, and the compatible voltage source recommended for the motor. You can ignore the rotor inertia of the motor.

An example is given in the supporting document!

DESIGN

There are three elements to complete the design of your car.
The second element is the **energy source (battery).**

You are allowed to choose one among the options below:
Note that as the weight of the battery is proportional to its voltage capacity!

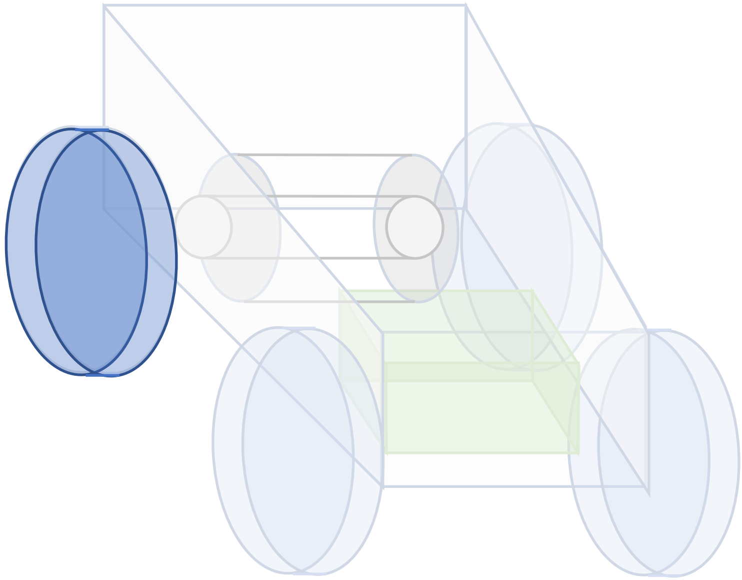


12V battery: <u>100 gram</u>
24V battery: <u>200 gram</u>
48V battery: <u>400 gram</u>

DESIGN

There are three elements to complete the design of your car.

The third element you are supposed to design is the wheel, or more specifically: the radius of the wheel. You can either connect a tiny wheel to your car, or a really big one.



Based on the radius of the wheels, the distance covered in a single full-rotation changes. However, the weight of the car and the rotational inertia of the wheel will also change by the radius you select!

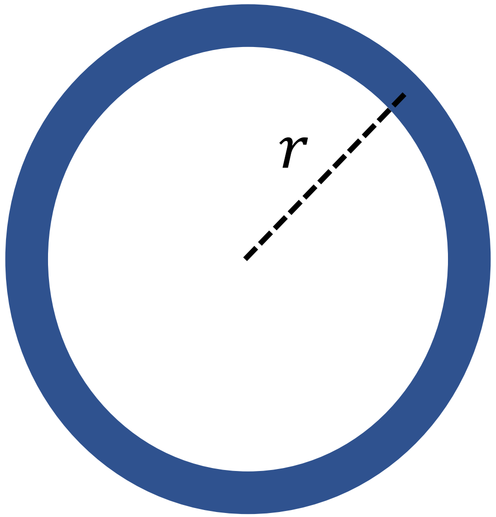
You can set the radius to any value between 0.1 m to 0.5 m.

Total mass and rotational inertia of the wheel set is as follows:

$m_w = 0.5r\ kg$ (r in meters)

$I_w = m_w r^2\ kgm^2$

Wheel from the side:



DESIGN

The bare output of a DC motor is rarely sufficient to drive a toy car. Therefore, we normally need a gear-box that would elevate the torque output of the motor, at the expense of the shaft velocity.

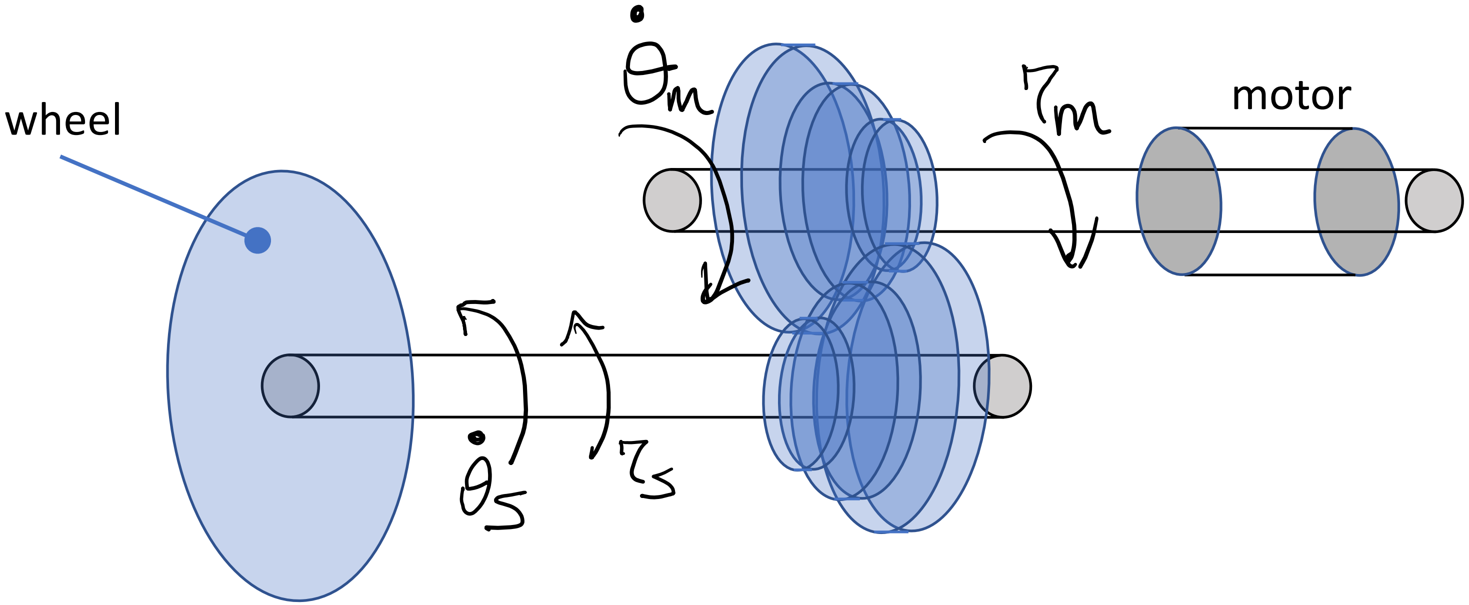
Here, assume that we have a gear-box that multiplies the torque of the motor by 5, and shaft velocity by 1/5:

(This is a static relationship. Assume that the gear-box does not have a dynamic effect on the motor.)

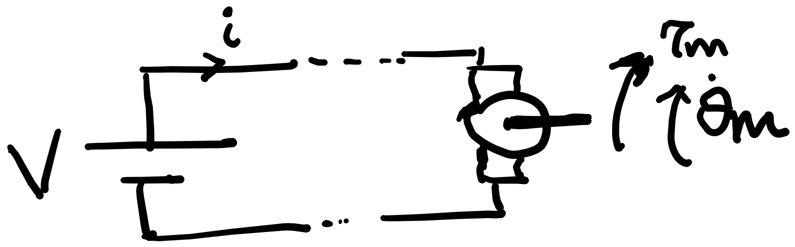
τ_m and $\dot{\theta}_m$ are the output of the motor. Those are related to the torque and velocity transmitted to the shaft of the wheel:

$$\tau_s = 5\tau_m$$

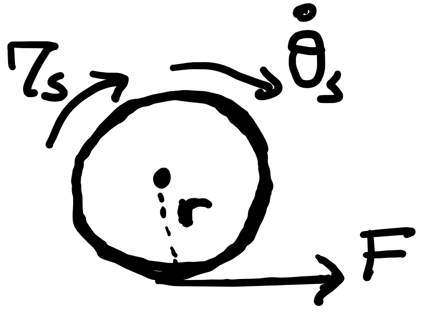
$$\dot{\theta}_s = \frac{1}{5}\dot{\theta}_m$$



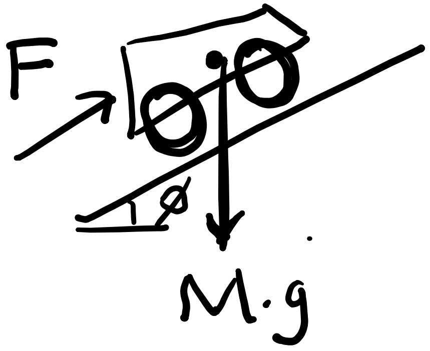
MODELLING TIPS:



- The vehicle is driven by a DC motor. Therefore, the relation between the input (voltage) and the output (motor torque, or motor velocity) should be obtained.



- The motor torque/velocity are related to the torque/velocity delivered to the shaft of the wheel (check the gear ratio!).
- On the wheel, there is a ground reaction in the direction of the vehicle motion. It is that force, F, that pushes the vehicle forward.
- The dynamics between the torque delivered to the shaft of the wheel and the ground reaction force, F, should be obtained. A single wheel-motor model would be sufficient to capture it.



- The ground reaction force and the motion of the vehicle are related through the motion of the vehicle. You can ignore any additional dynamic factors such as drag resistance.

- The total mass of the vehicle is the sum of the mass of the individual components. Your design choices will affect this parameter.

m_b: mass of the battery

m_c: mass of the chassis (200 grams)

m_w: mass of the wheel set

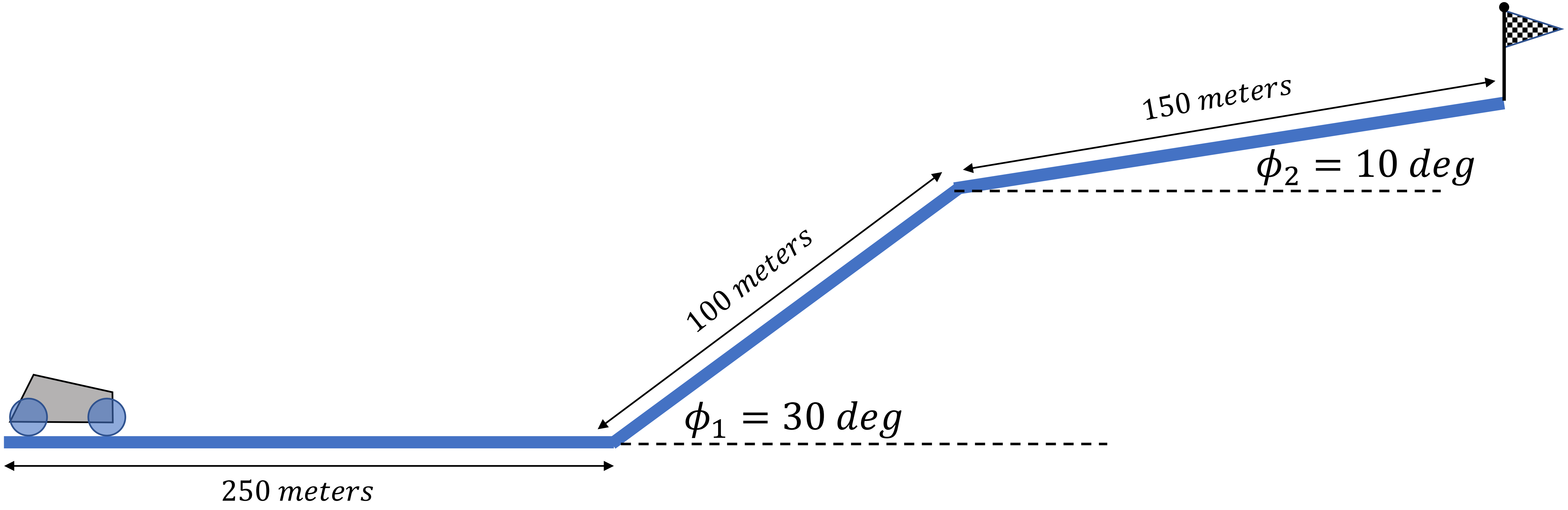
m_m: mass of the motor

$$M = m_w + m_c + m_m + m_b$$

PARKOUR

Below is the profile of the parkour on which your design will be tested. The car will have to climb up!

In your simulation, there should be a block that calculates the climbing angle of the road as the car moves forward. Note that, while the car climbs up an inclined road, there will be a downward force pulling the car backward. Your simulation should account for that using the information produced by this block.



SIMULATION

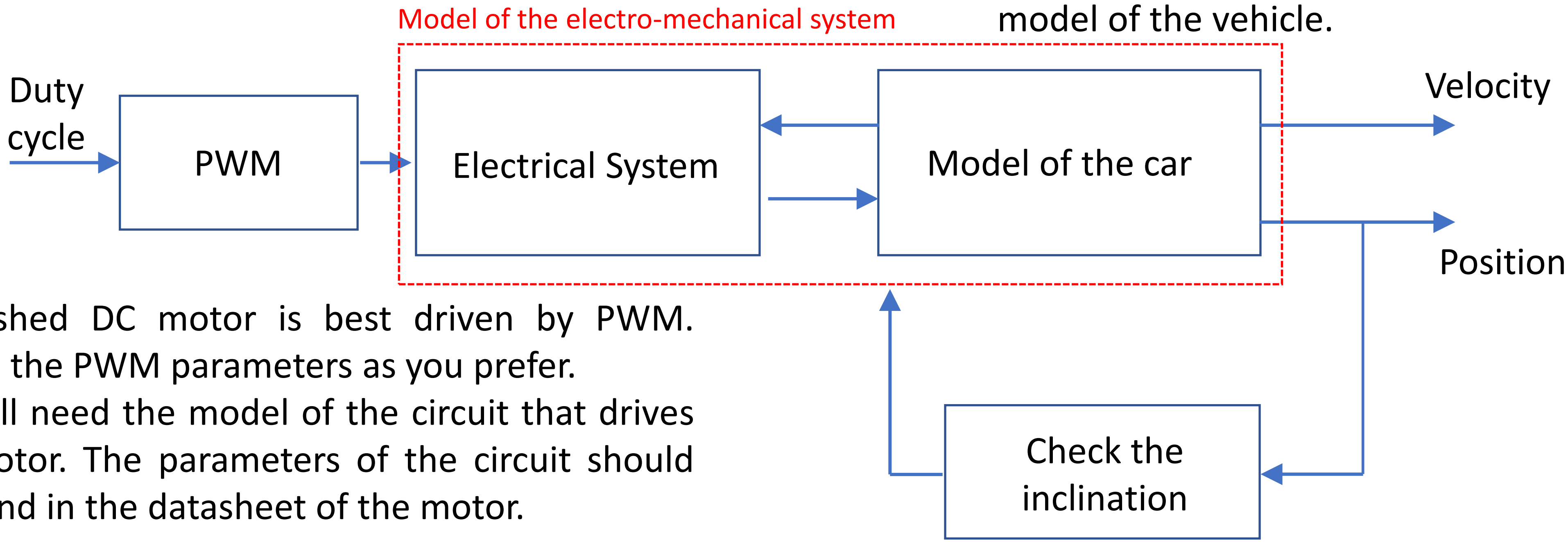
In order to simulate the motion of the car, you will need to model the relationship between the electrical input provided by the electrical circuitry and the velocity of the car.

Here is some hints that could help:

The output of the motor depends on the mechanical model of the vehicle.

Recommended Simulink model parameters:

- Fixed-step
- Solver: ODE4
- Step size: 0.001 sec



A brushed DC motor is best driven by PWM. Design the PWM parameters as you prefer.
You will need the model of the circuit that drives the motor. The parameters of the circuit should be found in the datasheet of the motor.

The simulation file should check the inclination angle of the road for each displacement value. This block should calculate the angle and feed it back to the model of the system.

Note that this is not the entire solution. This diagram is just provided to give you an idea about the simulation file. You should implement the missing parts to complete the tasks!

Once the simulation is complete:

You are expected to use your simulation to prepare the following:

1) What is the minimum amount of time it takes for your design to complete the parkour? (Hint: Just set the duty cycle to max and see what you get!)

2) Repeat #1 for another design you have. Just change one of the design parameters as you like and see how the performance is affected. You are expected to explain the reasons for any difference!

3) Modify your code a little to control the velocity of the car. The desired speed is 0.5 m/s. In other words, make your car go at the desired velocity throughout the parkour.

- The fastest car and the most accurate controller will get a trophy! (Don’t get high expectations, it will be a cute little 3D-printed cup.)

GRADING

A correct model and simulation (regardless of the performance of the car): 60%

Implementing a velocity controller: 20%

Report (includes the simulation file, results of all 3 tasks described): 20%


SHOW ME
WHAT YOU
GOT