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Exercise Sheet 5

Presentation during exercises in calendar week 26

Exercise 5.1 – Cart Pendulum

Imagine the given cart pendulum from figure 1. The cart pendulum consists of two rigid bodies, the *Cart* and the *Pendulum*. The pendulum itself consists of two elements, a spherical mass and a massless link. The model has two degrees of freedom:

- q_0: the x-translation of the body *Cart*.
- q_1: the rotation around the y axis of the body *Pendulum*.

The movement of the pendulum can be controlled by a force u_0 acting in horizontal direction on the cart.

Cart:

- Cuboid
- x-length= 0.5m, y-length = 0.2m, height = 0.2m
- mass = 10.0kg

Pendulum:

- Massless link: length = 0.5m
- Sphere: radius = 0.1m, mass = 1.0kg

Formulate an optimal control problem to find a *swing-up* trajectory $x\,(t)$ with minimal energy consumption from the static initial state $q\,(0) = \begin{bmatrix} 0 & \pi \end{bmatrix}$ towards the final static state $q\,(T) = \begin{bmatrix} 0 & 0 \end{bmatrix}^T$. The *swing-up* should be performed in $5s$ and the force characteristics on the cart are given with:

$$-150N \leq u \leq 150N \tag{1a}$$

$$-50\frac{N}{s} \leq \dot{u} \leq 50\frac{N}{s} \tag{1b}$$

- Implement the problem formulation for minimum energy based on the template from the following folder:

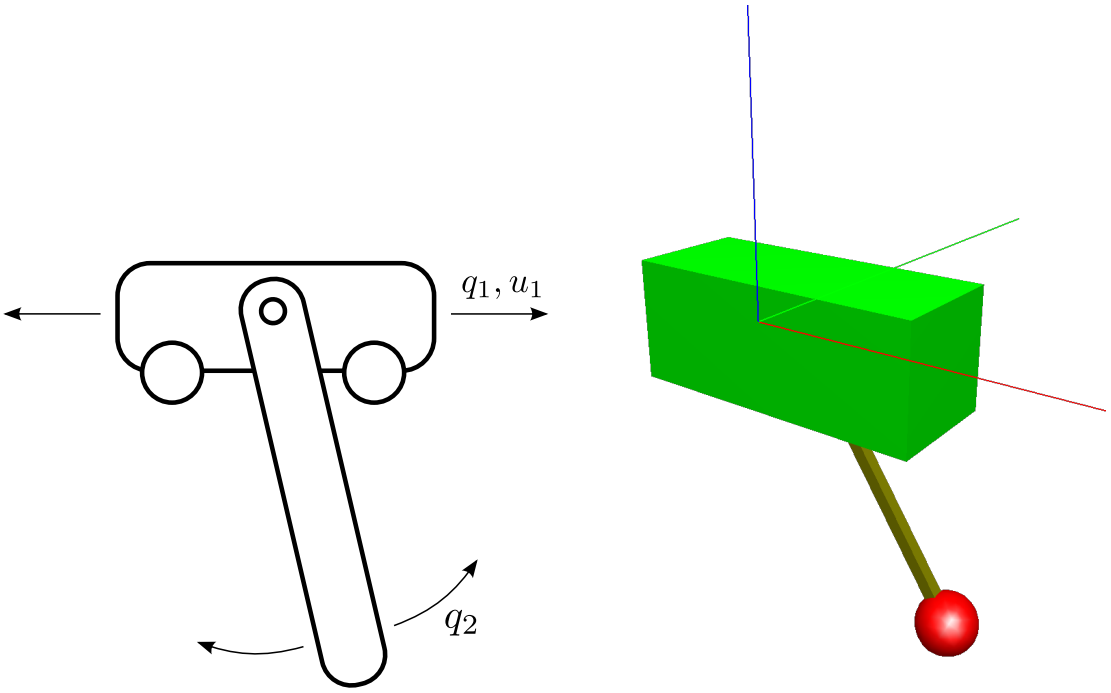

Figure 1: Cart pendulum and MeshUp model

`/Cart_Pendulum_Template/`

- Unfortunately, the actuation-system was not well assembled and overheats again. Force-output drops to $100N$ - how fast can the pendulum now swing up? (change `of_sca` to 1.0 and `u_sca` to 10.0)