Exercise 1
Consider a planar 3R robot with unitary link lengths as in Fig. 1. Taking into account the robot redundancy, a velocity control scheme is active so as to track desired end-effector position trajectories while trying to locally maximize the minimum Cartesian distance of the robot body from the obstacles.

- In the shown configuration \( q = (30^\circ, -30^\circ, 30^\circ) \), the end-effector is assigned a unitary velocity \( v \) in the positive \( x_0 \) direction. Specify the velocity control scheme and provide the associated numerical value of the command vector \( \dot{q} \in \mathbb{R}^3 \).
- Compare with a minimum velocity norm solution that neglects the presence of the obstacle.

![Figure 1: A planar 3R robot moving in the presence of an obstacle](image)

Exercise 2
The two-mass flexible system in Fig. 2 moves under gravity and is subject to a control force \( F \). The position coordinates \( q_1 \) and \( q_2 \) have their zero in a position where the elastic spring is undeformed.

- Derive the dynamic model assuming that all friction effects can be neglected.
- Determine all forced equilibrium configurations of the system.
- Design a feedforward plus linear feedback control scheme using only measurements of the position \( q_1 \) and velocity \( \dot{q}_1 \) of the first mass, which is able to regulate the position of the second mass to a constant desired position \( q_{2,d} \).
- Prove the global asymptotic (actually, exponential) stability of the desired closed-loop equilibrium. Hint: The closed-loop system dynamics is affine, and a simple analysis can be made by linearizing the system around the desired equilibrium, which removes constant terms.

![Figure 2: A system of two masses \( m_1 \) and \( m_2 \), coupled by an elastic transmission of stiffness \( k \)](image)

[180 minutes; open books]