Control of industrial robots

(Prof. Rocco)

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Name: ....

University ID number:...............................

Signature:......................................
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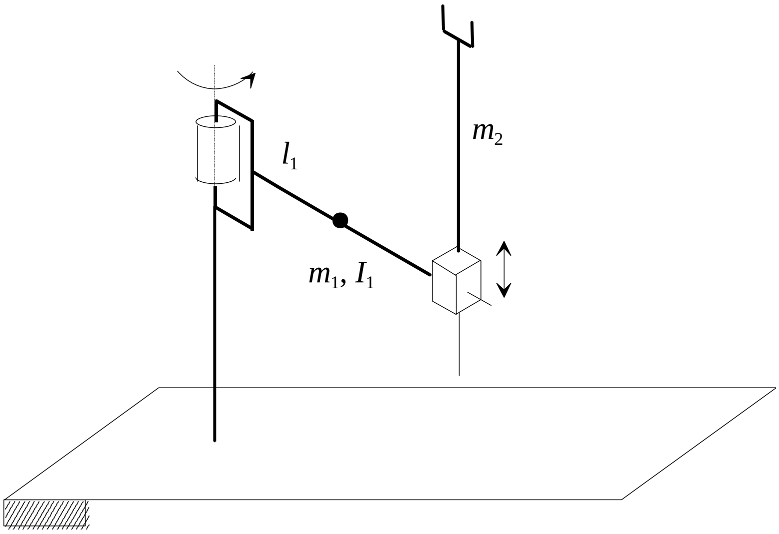
Warnings:

- This file consists of **8** pages (including cover). All the pages should be signed.
- During the exam you are not allowed to exit the room for any other reason than handing your work or withdrawing from the exam.
- You are not allowed to withdraw from the exam during the first 30 minutes.
- During the exam you are not allowed to consult books or any kind of notes.
- You are not allowed to use calculators with graphic display.
- Solutions and answers can be given **either in English or in Italian**.
- Solutions and answers must be given **exclusively in the reserved space**. Only in the case of corrections, or if the space is not sufficient, use the back of the front cover.
- The clarity and the order of the answers will be considered in the evaluation.
- At the end of the test you have to **hand this file only**. Every other sheet you may hand will not be taken into consideration.

Use this page ONLY in case of corrections or if the space reserved for some answers turned out to be insufficient

Exercise 1

Consider the manipulator sketched in the picture:



1.1 Find the expression of the inertia matrix of the manipulator.

1.2 Compute the gravitational terms for this manipulator.

1.3 Write the dynamic model of this manipulator.

1.4 What are the dynamic parameters of this model that can be identified with suitable experiments?

Exercise 2

Consider a P/PI control system for a rigid servomechanism.

Assume the following values for the physical parameters:

$J_m = 0.02\ Kg\ m^2$

$D_m \cong 0$

$J_l = 3\ Kg\ m^2$

$n = 10$

2.1 Design a speed PI controller in such a way to obtain a crossover frequency $\omega_{cv} \cong 200$ rad/s

2.2 Design a P position controller in such a way to obtain a crossover frequency $\omega_{cp} \cong 20$ rad/s.

2.3 Assume now that the transmission joint has some flexibility. Sketch the typical root locus for the speed control loop in this case.

2.4 Determine the minimum value of the stiffness constant K_{el} such that the design of the controller made at point 2.1 is adequate.

Exercise 3

3.1 Consider a cubic trajectory with zero initial and final speeds. Write the parametric expression of the trajectory, to be used in the kinematic scaling method.

3.2 Based on the parametric expression previously determined, derive the expressions of the maximum speed and acceleration as a function of the duration of the trajectory and of the distance to cover.

3.3 Assume now that the trajectory discussed previously has to displace the variable q from the initial value $q_i = 0$ to the final value $q_f = 30$ and that the maximum values of speed and acceleration are: $\dot{q}_{\max} = 60$, $\ddot{q}_{\max} = 20$. Compute the minimum positioning time.

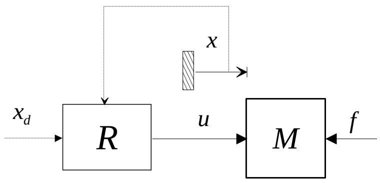
3.4 Briefly explain what is the goal of the dynamic scaling method and what is the main difference from the kinematic scaling method.

Exercise 4

4.1 Explain what is the mechanical impedance and for what reason it is interesting to assign a prescribed impedance to a mechanical system.

4.2 With reference to the one degree of freedom system sketched in the picture, suppose that you want to design an implicit impedance controller, which makes use of the measurement of the force at the end-effector.

Draw the block diagram of the controller.



4.3 Explain what result can be obtained with the control scheme previously described.

4.4 Explain what is the advantage of an implicit control scheme with respect to an explicit one.