

Industrial Automation and Robotics

PROF. ROCCO

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NAME:

UNIVERSITY ID NUMBER:

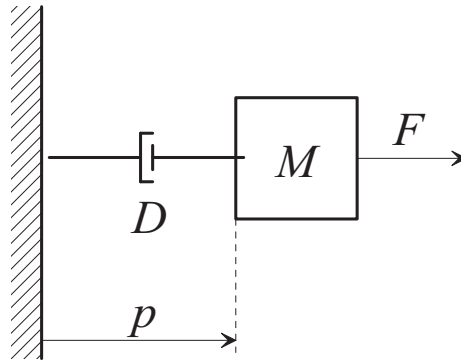
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Warnings

- This file consists of **8** pages (including cover).
- 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.

EXERCISE 1

Consider the mechanical system depicted in the picture:



The system is composed by a body of mass M subjected to a viscous friction force, proportional to the speed through the coefficient D .

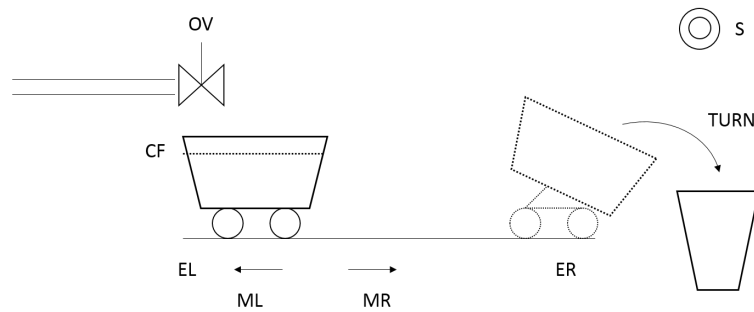
1. Find the transfer function from the force F to the speed v .
2. Setting $M = 1$, $D = 2$, find the dc gain of the transfer function

3. Sketch the plot of the step response of the above system.

4. Define what a low-pass filter is and give the precise definition of its bandwidth.

EXERCISE 2

Consider the automatic cart depicted in the picture:



In the initial state, the cart is to the left of the rail and the valve is closed. When the operator presses a button, the valve is open until the cart is full, then the cart has to move to the right until it reaches the end of the rail. At this point the cart is rotated for 10 seconds to unload it, after which it returns to the left of the rail. Two end of rail signals (**ER** and **EL**), one signal that informs that the cart is full **CF**, and one signal corresponding to the button pressed (**S**) are available. Two commands for moving the cart to the right (**MR**) and to the left (**ML**), one for turning the cart (**TURN**) and one for opening the valve (**OV**) are available.

1. Explain what is a Sequential Function Chart and what are its main elements

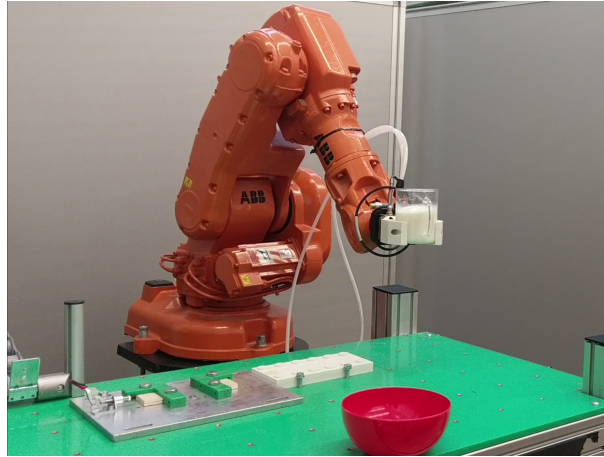
2. What does it mean that a transition in a SFC is superable?

3. Sketch a Sequential Functional Chart (SFC) that might be used to program a PLC in charge of the logic control of the automatic cart previously described.

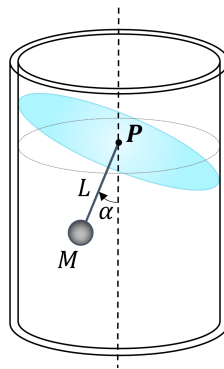
4. Explain how in a SFC a IF-THEN-ELSE programming structure can be implemented.

EXERCISE 3

Consider the robot carrying a glass with liquid sketched in the picture:



The robot should be moved in such a way to avoid spilling of the liquid from the container. In a first approximation, the sloshing dynamics of the liquid can be modelled with a pendulum, see the following picture:



For simplicity, assume that the pendulum moves on a vertical plane.

1. Explain what are the direct and the inverse kinematics problems for a robotic manipulator.

2. How many solutions does the inverse kinematics for an anthropomorphic manipulator have? Characterize such solutions.
3. Write the equations of a dynamic system that describes the motion of the pendulum (when the robot is still).
4. Write the general equation that allows to find the equilibrium states in a dynamic system. Apply such formula to find the equilibrium states for the pendulum at hand.