Industrial Automation and Robotics

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NAME:

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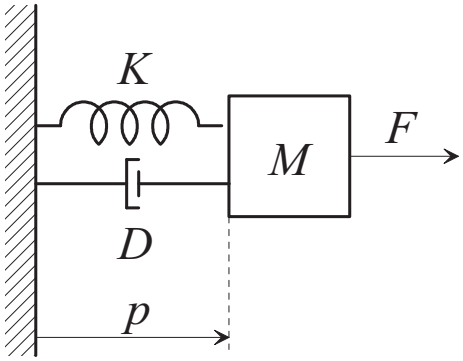
SIGNATURE: _____

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

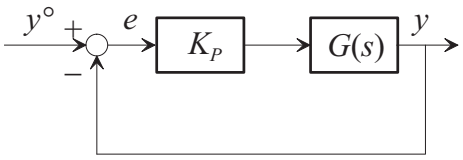
Consider the mechanical system depicted in the picture:



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

1. Setting $M = 1$, $K = 100$, $D = 20$, find the transfer function $G(s)$ from the force F to the position p.

2. Consider now the block diagram sketched in the picture:



where $K_P = 10000$, while $G(s)$ is the transfer function computed previously. Sketch the asymptotic Bode plot of the magnitude of the loop transfer function of the control system.

3. Compute the crossover frequency and check that the phase margin of the control system is positive.

4. Compute the expression of the sensitivity function of the system and sketch the asymptotic Bode plot of the magnitude of this transfer function.

EXERCISE 2

1. Explain precisely what is the meaning of the symbol `--|  |--` in a Ladder Diagram.

2. Consider now a logical system that has to implement the function:

   if A
   X = (A or B); Y = X;
   else
   X = (A and B); Y = not(X);

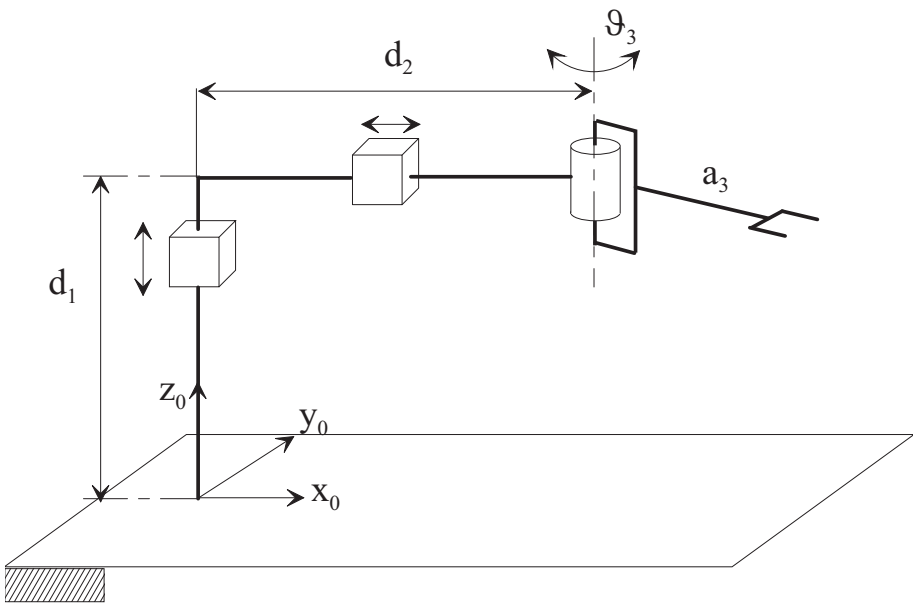
   Sketch a ladder diagram that implements this logical function.

3. Suppose that during the exploration of the Ladder Diagram by the PLC one of the inputs, **A** or **B**, changes its value. Discuss whether or not this will change the evaluation of the states of **X** and **Y**.

4. Sketch a Sequential Function Chart that implements an if-then-else programming structure and comment such sketch.

EXERCISE 3

1. Consider the following robot manipulator with 3 joints (prismatic, prismatic, and rotational):



Find the expression of the direct kinematics of the robot, in terms of the position coordinates of the end effector with respect to the joint variables d_1, d_2, and ϑ_3.

2. Write the expression of the Jacobian of the manipulator of this exercise.

3. Characterize the singularities of the manipulator of this exercise.

4. Take one of the singular configurations determined previously: show that in this configuration the motion of the end effector looses one degree of mobility.