

# Industrial Automation and Robotics

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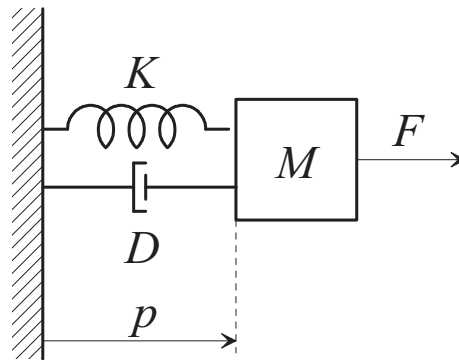
## Warnings

- 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

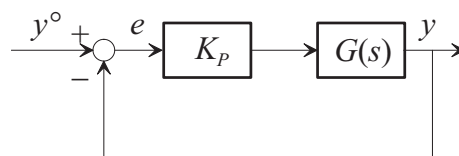
Consider the mechanical system depicted in the picture:



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

1. Setting  $M = 1$ ,  $K = 1$ ,  $D = 2$ , 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  $K_p = 100$ , 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. Check that the closed loop polynomial of the system (denominator of the transfer function from  $y^o$  to  $y$ ) has negative real part roots.



3. Briefly explain what is a hard real-time system. What are the main features of a hard real time operating system?

4. Briefly explain what is the token bus (or token ring) method for accessing a bus in a digital network.



3. Assume a travel time  $T = 2s$ . Design a time law, which covers the path determined in the previous step, using a cubic dependence on time.

4. Compute the maximum linear velocity of the end effector along the trajectory designed in the previous step.