Last name **Name** **student ID No.:**

Section 4: STABILITY OF LINEAR DYNAMIC SYSTEMS

A dynamic process $G_p(s)$ has the following transfer function:

$$G_p(s) = \frac{1}{(s+1)^2\left(\frac{s}{10}+1\right)}$$

The measuring device utilized to measure the controlled variable has the following transfer function:

$$G_H(s) = e^{-\frac{s}{10}}$$

Part A: *Root locus*

For $G_{OL}(s)$ to be approximated with a **Padé approximation of 1st** order:

A1.Plot the *root locus* **by means of SisoTool** and attach it here

A2.Is your plot the direct or the inverse root locus?
A3. Quantify the Break-Away-points
A4. If any, find the Kc of the controller for which the system in closed-loop is marginally stable.

A design requirement is available for this process, the **damping ratio has to be 0.71**.

A5.Find $K_{c,P}$ of the **proportional controller** for which the system respects the design requirement.
A6.Plot here the *root locus* with the closed loop poles satisfying the design requirement “damping ratio = 0.71” (*Hint: at this point, it may be convenient to look also at the related question* C1).
A7. Individuate the dominant poles of the “second-order Dominant Pole Approximation” of G_{OL} approximated with Padé.
A8.In your opinion would be such a “second-order Dominant Pole Approximation” a reasonable one, why?

In addition, a tunable PID controller is available:

$$G_{PID}(s) = K_c\left(1 + \tau_D s + \frac{1}{\tau_I s}\right)$$

and it is chosen to tune it **by performing pole/zero cancellation**.

A9.Where are located the pole and zeros of the PID controller?
A10. Find $K_{c,PID}$ of the PID controller for which the system respects the design requirement.

A11. Plot here the *root locus* with the closed loop poles satisfying the design requirement “damping ratio = 0.71” (*Hint: at this point, it may be convenient to look also at the related question* C3).

Part B: Frequency response

Considering the feedback control system with the original $G_P(s)$, $G_H(s)$ and the ***PID controller*** $G_{PID}(s)$ being the result of the above tuning

B1)Plot the **Bode Diagrams** by means of Matlab or SisoTool resources and attach it here

B2)Does a **crossover** frequency exist? How much is it?

B3)Decide if the Bode stability criterion is applicable
B4)If yes, is the above system closed-loop stable?

B5)Plot and attach here the **extended Nyquist diagram** *together with the unit circle* by means of Matlab or SisoTool resources, then discuss it in details

B6)Check, on the base of the **Nyquist** stability criterion, if the above system is closed-loop stable

Part C: Dynamic responses in the time domain

Considering the feedback control system with the original $G_P(s)$, the original $G_H(s)$ and the ***P controller*** with the gain $K_{c,P}$ previously determined

C1. Plot the **closed-loop** system dynamic response to a unit step in **set point** by means of Matlab or SisoTool resources with the most of its relevant characteristics and attach it here.

C2. Is the proportional controller capable of providing an effective set **point tracking**?

Considering the feedback control system with the original $G_P(s)$, the original $G_H(s)$ and the ***PID controller*** $G_{PID}(s)$ being the result of the above tuning

C3. Plot the **closed-loop** system dynamic response to a unit step in **set point** by means of Matlab or SisoTool resources with the most of its relevant characteristics and attach it here.

Part D:

= = =