DO NOT START UNTIL INSTRUCTED BY EXAMINER

Exam Policy:

- open book
- open notes
- calculators allowed; no cell phones

Some Remarks:

- There are 2 problems. Read all questions and point values. Max score is 100
- Write your name on every sheet of paper you hand in.
- Best of luck
PROBLEM 1 (60pts)

Consider the unity feedback system where

\[ P(s) = \frac{1}{(s+1)(s-2)}. \]

1. Suppose we use a proportional controller \( K(s) = k, \ k \geq 0 \). Is it possible to achieve closed loop stability for some \( k \)?

2. If \( K(s) = k(s + 2)/(s + 5), \ k > 0 \), provide the maximum range of \( k > 0 \) to stabilize the closed loop.

3. Can all closed loop poles be made real for such a stabilizing \( K(s) \)?

4. What will be the real parts of the closed loop poles as \( k \to \infty \)?

5. What will be the steady state error \( e \) to a step input \( r \) as \( k \to \infty \)?

6. Suppose we use \( K(s) = k(s+1) \). Can we stabilize the closed loop for some \( k \)? Explain.

\[ e = r - y \]

\[ \begin{align*}
1. \quad & \varphi(s) = (s+1)(s-2)+k = s^2 - s - 2k + k \\
& \text{not all roots have same sign} \Rightarrow \text{impossible}
\end{align*} \]

\[ \begin{align*}
2. \quad & \varphi(s) = (s+1)(s-2)(s+5) + k(s+2) \\
& = s^3 + 4s^2 + (k-7)s + 2k - 10 \\
& \Rightarrow k > 7 \text{, } 2k > 10 , \ 4(k-7) > 2k - 10 \\
& k \geq 7, \ k \geq 5, \ k \geq 9 \Rightarrow (k \geq 9)
\end{align*} \]

\[ \begin{align*}
3. \quad & \alpha = -\frac{-\gamma + 2}{2} = -1 \\
& \text{check b.p.} \\
& D'N - DN' = 0 \\
& \text{If so in RHP} \Rightarrow \text{impossible}
\end{align*} \]
PROBLEM 2 (40 pts)

1. True or False: A type-1 system always produces zero steady state errors to step disturbances at the input of the plant. $\text{F}$

2. True or False: A type-$k$ system produces zero steady state errors to reference inputs of the form $r(s) = 1/s^k$ and its $m$-th time derivatives, for $m = 1, \ldots, k$. $\text{T}$

3. True or False: We can always stabilize a system with PID controllers. $\text{F}$

4. Consider each of the following diagrams below. Next to each diagram mark clearly in the circles: (T) if the diagram can possibly represent a root locus diagram; (F) if the diagram cannot possibly be a root locus diagram. (note that we consider only the standard root locus diagram, i.e., $k \geq 0$.)

- Diagram 1: $\text{T}$
- Diagram 2: $\text{F}$
- Diagram 3: $\text{F}$
- Diagram 4: $\text{T}$