Solve the following questions for the given transfer function.

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        0.5 s + 1.25
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 s^3 + 2.5 s^2 - 9.5 s - 21
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1. Calculate the poles and zeros of the system using MATLAB. Is the open-loop system stable? Is the system minimum-phase?

2. Obtain a state-space representation for the system.

3. Analyze the controllability and observability of the obtained state-space representation. Is it possible to design a state feedback controller and a state observer for this representation? If the obtained state-space model is uncontrollable, decompose it into controllable and uncontrollable subsystems. Similarly, if the state-space model is unobservable, decompose it into observable and unobservable subsystems.

4. If the state-space representation obtained in the previous part is not minimal, derive a minimal realization for the system.

5. Plot the open-loop response of the system (if stable) for a unit step input and arbitrary initial conditions.

6. Simulate the closed-loop system based on the obtained state-space representation using negative unit feedback. Plot the step response of the closed-loop system and determine its poles and zeros.

7. Design a state feedback controller for the obtained state-space representation such that the poles of the closed-loop system are placed at desired locations on the left side of the jw-axis. Plot the step response, state variables, and control signal of the closed-loop system. Compare the poles and zeros of the open-loop and closed-loop systems.
   Note: Perform this step for both far and near pole placements, and compare the control signals and state feedback gains obtained in each case.

8. Design a static tracking controller for the obtained state-space representation.

9. Design an integral tracking controller for the obtained state-space representation.

10. Compare the responses of the two tracking controllers designed in questions 8 and 9, analyzing the results based on the following perspectives:

- Tracking performance
- Robustness in the presence of parameter changes in the model
- Closed-loop system performance when subjected to constant disturbances

11. Design a full-order observer for the obtained state-space representation of the system. What are the criteria for selecting the observer poles? Plot the state variables and estimation error. For this question, choose two sets of slow and fast observer poles, design the corresponding full-order observers, and compare the state variables and main estimated state variables for each observer.

12. Change one of the system parameters and use the previously designed observer to estimate the states of the modified system. Analyze the result.

13. Design the closed-loop system using the estimated states such that the closed-loop poles are on the left side of the jw-axis, with a step response that exhibits acceptable overshoot and settling time. Plot the step response and state variables of the system, assuming the system states are not directly accessible and the state feedback relies on the estimated states from a full-order observer.

14. For the given system, design a state feedback tracking controller with a full-order observer.

15. Derive the optimal state feedback gain for the system to minimize the following cost function for various values of matrix R and matrix Q. First, keep matrix Q fixed and vary matrix R; then keep matrix R fixed and vary matrix Q. Compare the simulation results for each case.

$$J = \int (x^T Q x + u^T R u) dt$$