

- 5.22. For the distillation column of Exercise 5.15, design a two-output, reduced-order observer using the MATLAB (CST) command *place* such that the observer poles are placed in Butterworth pattern of radius, $R = 21$. With the resulting observer and the regulator designed in Exercise 5.9, form a reduced-order compensator and compare the initial response and required inputs of the compensated system for the initial condition $\mathbf{x}(0) = [1; 0; 0; 0]^T$, with the corresponding values obtained in Exercise 5.18.
- 5.23. Using SIMULINK, simulate the tracking system for the inverted pendulum on a moving cart with the reduced-order compensator designed in Example 5.20, including a measurement white noise of intensity (i.e. *power* parameter in the *band-limited white noise* block) when the desired plant state is $\mathbf{x}_d = [0; 1; 0; 0]^T$.
- 5.24. Using SIMULINK, test the *robustness* of the full-order compensator designed (using linear plant model) in Example 5.18 in controlling the plant model described by the *nonlinear* state-equations of Eqs. (3.17) and (3.18) when the desired plant state is $\mathbf{x}_d = [0; 1; 0; 0]^T$. (Hint: replace the *subsystem* block in Figure 5.22 with a *function* M-file for the nonlinear plant dynamics.)

References

1. Kreyszig, E. *Advanced Engineering Mathematics*. John Wiley & Sons, New York, 1972.
2. Friedland, B. *Control System Design – An Introduction to State-Space Methods*. McGraw-Hill International Edition, Singapore, 1987.
3. Kautsky, J. and Nichols, N.K. *Robust Eigenstructure Assignment in State Feedback Control*. Numerical Analysis Report NA/2/83, School of Mathematical Sciences, Flinders University, Australia, 1983.