Closed book, closed notes portion of exam. Write your answers in the space provided below each question.

1) [3 pts] What is the primary advantage of the state feedback controller design vs. the proportional or proportional-derivative (PD) controller design used in "classical" control?

2) [3 pts] How can you determine when a realization \(( \dot{x} = Ax + Bu, \quad y = Cx + Du )\) for a matrix transfer function \(H(s) = H(s)u(s)\) is irreducible?

3) [4 pts] What determines the number and type of state variables in a model of a physical system?
4) [4 pts] Is there a practical limit on the values selected for state feedback gains? Why or why not?

5) [4 pts] How is the design process for linear quadratic regulators (LQR) different from the design process for state feedback control that we studied in detail?
Closed book, one 8.5x11 inch page of notes allowed. Work each of the problems below as completely and thoroughly as possible.

- You may use Matlab in your solutions where appropriate, but not to solve entire problems.
- You may use pre-written “M” files, but not any other textual material available in any form on the computer (websites, Word documents, text files, etc.).
- You may NOT use Maple except to check an answer.

6) [24 pts] A second order system is given below. Assume that the input is \( u(t) = 1 + e^{-t} = 1 + \exp(-t) \).

\[
\frac{dx_1}{dt} = -x_1 - 2x_2 + u(t), \quad x_1(0) = 0 \\
\frac{dx_2}{dt} = +2x_1 - 6x_2, \quad x_2(0) = 3 \\
y = x_2
\]

a) use the eigenvector method of the text to design a full state observer with eigenvalues -5, -6 for this system.

b) use Matlab to simulate the response of the "true" system and its observer for 4 seconds—set the initial condition to 1 for both estimated state variables.

c) Turn in all code and a plot of the results for (b) with all variables clearly identified.

7) [38 pts] Given the system described by the diagram below,

d) find a 4th order set of state variable equations that is a valid realization for the system,

e) use any valid method (except calling the Matlab functions place or acker) to design a state feedback controller \( u = Fy - Kx \) that will have eigenvalues at -2, -5, -6, -7 (find both \( K \) and \( F \)) and

d) use any valid method to design a partial observer with eigenvalues of -8, -9 that will estimate all states not directly observable in the output, \( y \). Show all equations necessary to implement the partial observer.

Do NOT do any Matlab simulations - simply find the appropriate matrices & equations

\[
\begin{bmatrix}
\frac{1}{s+1} & \frac{1}{s+1} & \frac{1}{s+3}
\end{bmatrix}
\begin{bmatrix}
u \\
1 \\
1 + \frac{1}{s+4}
\end{bmatrix}
\rightarrow y_2
\]

8) [20 pts] For the matrix transfer function (one output, two inputs) given below,

a) find a 3rd order set of state equations

b) for what values of \( K \) is your system stable?

c) for what values of \( K \) is your system controllable?

d) for what values of \( K \) is your system observable?

\[
y(s) = \begin{bmatrix}
\frac{s + 4}{s^2 + 5s + K} & \frac{7}{s + 3}
\end{bmatrix} u(s)
\]