Problems #1-#5 are closed-book, closed-notes problems worth 5 pts each. Answer on this sheet. Problems #6, #7, and #8 are closed-book problems (worth 25 pts each), but you may use one page of formulas prepared in advance.

1) What are three of the four components of a block diagram for a linear, time-invariant system? What are two of the three basic forms for interconnecting sub-systems?

2) If a 2\textsuperscript{nd} order system's poles are moved with a constant imaginary part, what will the unit step responses have in common?

3) What factors influence the choice of state variables in any system?

4) What are the two parameters that define the electrical and mechanical coupling in a DC motor? What are the units of each of these parameters?

5) According to your text, what are the three major design criteria for control systems?
6) A mechanical system is shown below.
   a) Find the state variable equations for the system
   b) Find the transfer function $X_2(s)/F_a(s)$ for the system

![Mechanical System Diagram]

7) [25] A simple, closed-loop control system is shown below:

![Control System Diagram]

a) Find the natural frequency, damping ratio, and damped natural frequency of the closed loop system.

b) Determine the overshoot, peak time, and settling time for a unit step input to the closed loop system.

c) On a sketch of the complex plane, clearly indicate the region where a 1st order pole could be added to the closed-loop system without significantly changing the unit step response.
8) [25] Five transfer functions are given below. Identify which of the seven complex plane plots and which of the six unit step time responses is associated with each transfer function.

<table>
<thead>
<tr>
<th>Transfer Function</th>
<th>Complex Plane</th>
<th>Step Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_1(s) = \frac{10}{s^2 + 4s + 10}$</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>$G_2(s) = \frac{13}{s^2 + 2s + 13}$</td>
<td>Complex plane: ______</td>
<td>Step response: ______</td>
</tr>
<tr>
<td>$G_3(s) = \frac{10}{s^2 + 2s + 10}$</td>
<td>Complex plane: ______</td>
<td>Step response: ______</td>
</tr>
<tr>
<td>$G_4(s) = \frac{13}{s^2 + 14s + 13}$</td>
<td>Complex plane: ______</td>
<td>Step response: ______</td>
</tr>
<tr>
<td>$G_5(s) = \frac{13}{s^2 + 4s + 13}$</td>
<td>Complex plane: ______</td>
<td>Step response: ______</td>
</tr>
</tbody>
</table>

![Complex Plane Diagram]

- **A**: $G_1(s)$
- **B**: $G_2(s)$
- **C**: $G_3(s)$
- **D**: $G_4(s)$
- **E**: $G_5(s)$