In giving your answer, the answer alone is not enough. Make sure you clearly give your rationale for arriving at the answer. It must be clear to me how you arrive at your answer.

Point values: a=5, b=2, c=3, d=5, e=2, f=3, g=3, h=8, i=3, j=3, k=8

Formulae:

\[ G_1(s) = \frac{K_{ss}}{T \cdot s + 1} \]
\[ G_2(s) = \frac{K_{ss} \cdot \omega_n^2}{s^2 + 2 \cdot \zeta \cdot \omega_n \cdot s + \omega_n^2} \]

\[ \zeta = \frac{-\ln(\% \text{ OS}/100\%)}{\sqrt{\pi^2 + \ln^2(\% \text{ OS}/100\%)}} \]
\[ T_{s-2\%} = \frac{4}{\zeta \cdot \omega_n} \]

Sufficient Hurwitz conditions for stability:

\( n = 3: a_0 \cdot a_3^2 - a_1 \cdot a_2^2 < 0 \)
\( n = 4: a_0 \cdot a_3^2 + a_4 \cdot a_1^2 - a_1 \cdot a_2 \cdot a_3 < 0 \)
\( n = 5: a_2 \cdot a_5 - a_3 \cdot a_4 < 0 \) and \( (a_0 \cdot a_3 - a_1 \cdot a_2)^2 - (a_3 \cdot a_4 - a_3 \cdot a_5) \cdot (a_1 \cdot a_2 - a_0 \cdot a_3) < 0 \)

Final Value Theorem: \( f_{ss} = \lim_{s \to 0} s \cdot F(s) \)

Steady-state error constants:

\[ K_{p-ess} = \lim_{s \to 0} (G \cdot H) \quad K_v = \lim_{s \to 0} (s \cdot G \cdot H) \quad \text{and} \quad K_a = \lim_{s \to 0} (s^2 \cdot G \cdot H) \]

<table>
<thead>
<tr>
<th>Input</th>
<th>Type 0</th>
<th>Type 1</th>
<th>Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( e_{ss} )</td>
<td>( e_{ss} ) constant</td>
<td>( e_{ss} )</td>
</tr>
<tr>
<td>Step</td>
<td>( \frac{R_0}{1 + K_{p-ess}} )</td>
<td>( K_{p-ess} ) = constant</td>
<td>( \frac{R_0}{1 + K_{p-ess}} )</td>
</tr>
<tr>
<td>Ramp</td>
<td>( \frac{R_0}{K_v} )</td>
<td>( K_v = 0 )</td>
<td>( \infty )</td>
</tr>
<tr>
<td>Parabola</td>
<td>( \frac{R_0}{K_a} )</td>
<td>( K_a = 0 )</td>
<td>( \infty )</td>
</tr>
</tbody>
</table>
1. For the system shown at right, answer the following questions.

![System Diagram]

a. What is the closed-loop transfer function for the above system, including the pre-loop gain? Put this into a standard form.

b. What is $\omega_n$?

c. What is $\zeta$?

d. What is $K_{ss}$?

e. What is the characteristic equation?

f. For what values of $K_p$ is the system stable? Show work.

Go on to next page
g. What type of input gives a finite steady-state error? Explain.

h. Assume this type of input, at a unit level (i.e., \( X(s) = \frac{1}{s}, \frac{1}{s^2}, \frac{1}{s^3}, \) or something of this form). What would be \( e_{ss} \) for this unit input?

i. For what values of \( K_p \) will the system oscillate?
j. What will the closed-loop poles be when \( K_P = 0 \)? Show work.

k. Draw the root locus of this system. (Hint: This systems configuration matches that analyzed in class Wednesday, so \( \zeta \omega_n \neq f(K_p) \).)