Name: ________________________________

Student #: ________________________________

Instructions: You have 50 minutes to complete the four examination questions that follow. There is also one bonus question at the end. Do all your work on the pages attached to this sheet. The weighting of each problem is shown below. Neatness and organization in your work is important!!!

CLOSED BOOK, CLOSED NOTES, AND NO CALCULATORS ALLOWED!

Grades

1. ________________ (10 pts.)
2. ________________ (10 pts.)
3(a) ________________ (10 pts.)
3(b) ________________ (10 pts.)
3(c) ________________ (10 pts.)
4(a) ________________ (10 pts.)
4(b) ________________ (10 pts.)
4(c) ________________ (10 pts.)
4(d) ________________ (10 pts.)
Bonus ________________ (10 pts.)
Total ________________ (100 pts.)
1. Write down the transfer function of a PI compensator, and explain why it’s called by that name.

2. For what values of gain $K$ does the polynomial

$$s^4 + 6s^3 + 10s^2 + 18s + K$$

have all its roots in the left half plane?
3. For the following three pole/zero plots for $G(s)$, sketch the root locus for $1 + KG(s)$ as $K$ varies from $0$ to $+\infty$. Determine in each case all breakaway and break-in points.

(a) The two poles are at $s = -1$ and $s = -3$.

(b) There is a double pole at $s = -1$ and a zero at $s = -3$. 
(c) There are poles at $s = -4$, $s = -3$ and $s = 2$ and zeros at $s = -1$ and $s = 0$. 
4. Parts (a), (b), (c) and (d) are in reference to the following feedback control system.

(a) Sketch the root locus for $0 < K < \infty$, and specify on your sketch all breakaway points and asymptote intersections.

(b) Show that $s = j2$ is on the root locus and determine the value of the gain $K$ that achieves this closed loop pole.

(c) Determine the steady state tracking error for a unit ramp input when $K = 12$ and when $K = 100$.

(d) Determine in terms of $K$ the steady state error from a unit step disturbance ($w$ is the disturbance). What is the smallest achievable error from a unit step disturbance using the proportional control shown in the diagram?
WORKSHEET FOR PROBLEM 4.
BONUS QUESTION. For

\[ G(s) = \frac{n(s)}{d(s)} \]

and that \( n(s) \) has a root at \( s = 6 \). Show that there is a value \( K_0 \) such that for all \( K > K_0 \) the closed loop system must be unstable.