ME 431 Control Systems I
Midterm
October 2003

Time: 2 hours
Instructor: S. Habibi
Instructions: 1- Answer all questions
2- Calculators are allowed
3- Students may bring up to 1 page of letter-size notes

---

(33) Q1: The unit step response of a system with a transfer function G(s) is shown in Figure 1. Obtain:

a) G(s).
b) The damping ratio.
c) The natural frequency.
d) The DC gain

And:

e) Indicate how you can determine from the response that G(s) is 2[nd] order.
f) Provide a polar plot of the poles of G(s).
g) Indicate and show how the following can be determined from such a polar plot:
   i. natural frequency;
   ii. the damping ratio;
   iii. the settling time; and
   iv. the damped frequency of oscillation ($\omega_d = \omega_n\sqrt{1-\varsigma^2}$).
h) Specify the pole position that would lead to a damping ratio of $\zeta = 0.707$ and a settling time of 1 second.

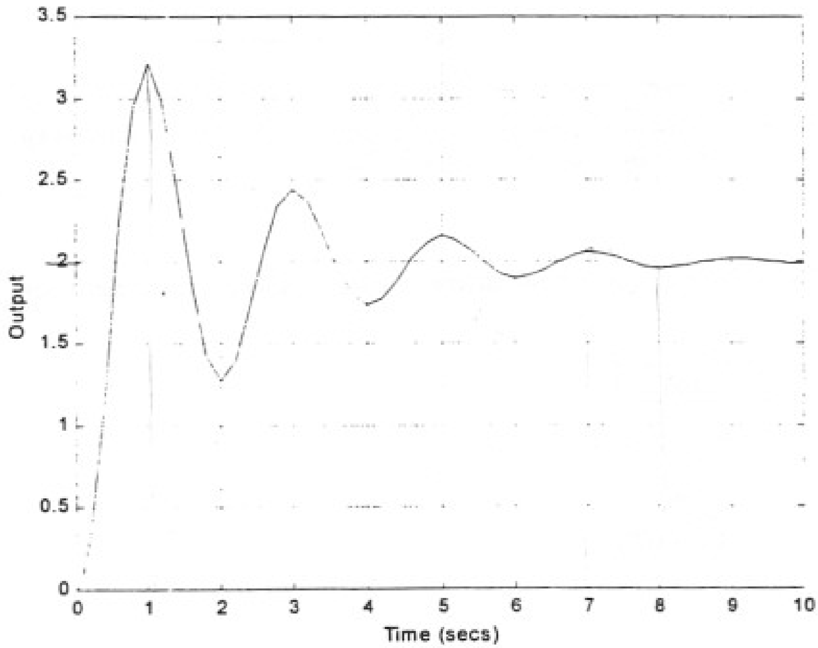

Figure 1

(34) Q2: For a system with the following open loop transfer function:

$$G(s) = \frac{K}{(s^3 + 2s^2 + 20s + 10)}$$

a) Determine the range of values of K for which the system is stable when used in a closed loop configuration with unity feedback.

b) Design a PID controller with unity feedback by using the Ziegler-Nichols method (the value of the gains should be calculated in their final form as Kp, Ki, and Kd).

c) Draw the block diagram of the system with its PID controller; in this diagram, clearly show the numerical values and structure of all transfer functions (that of the system and its PID compensator).

d) How is the system's performance affected when the following gains are changed:

   i. Proportional Gain.
   ii. Integral Gain.
   iii. Derivative Gain.

e) What is the effect of a right-hand-half-plane zero (closed loop) on the time response of a closed loop system.

f) Explain the difference between the dominance and the dynamic significance of a pole.

(23) Q3: Proportional control with the gain K_p is used for the control of the open loop system of Figure 2. The maximum proportional gain that can be used is $K_p = 30$.

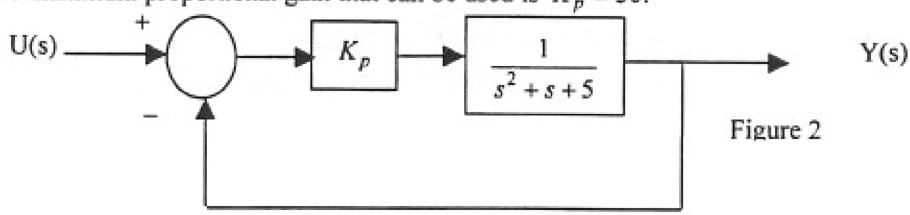

Figure 2

a) Given a unit step input, calculate the steady state error of the system with $K_p = 30$.

b) Design a proportional controller <u>with rate feedback</u> to achieve critical damping.

c) Draw the block diagram of the system obtained from b).

(10) Q4: Plot the Bode gain and phase diagrams for the following transfer functions:

(I) $$\frac{10\left(\frac{s}{100}+1\right)}{\left(\frac{s}{10}+1\right)\left(\frac{s}{1000}+1\right)}$$

(II) $$\frac{1000}{\left(s^2 + 10s + 100\right)}$$