ME 431/AE411 Control Systems I
Final- December 2001

Time: 3 hours
Instructor: S. Habibi

Instructions: **1- <u>Answer any 4 questions</u>**
2- Calculators are allowed
3- Students may bring up to 2 pages of letter-size notes
4- Question sheets are to be returned with the examination booklet

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(25) Q1: An electromechanical system is shown:

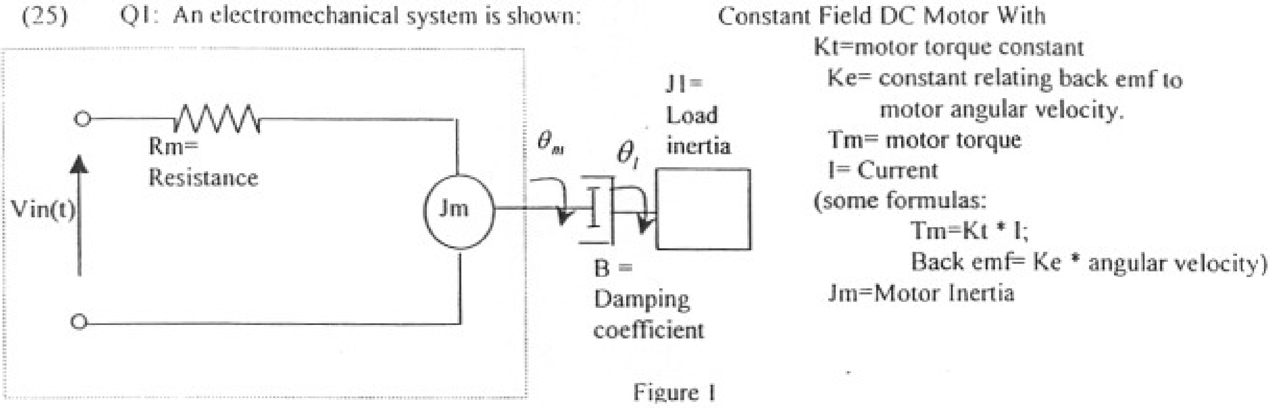

Figure 1

a) Write the differential equations of the system in Figure 1 and find their Laplace transform.
b) Draw a block diagram representation of the system in Figure 1 by using the equations obtained from a (do not reduce or simplify the block diagram).
c) Use Mason's Gain Formula to obtain the transfer function $T_M(s) = \frac{R(s)}{C(s)}$ of the System in Figure 2.

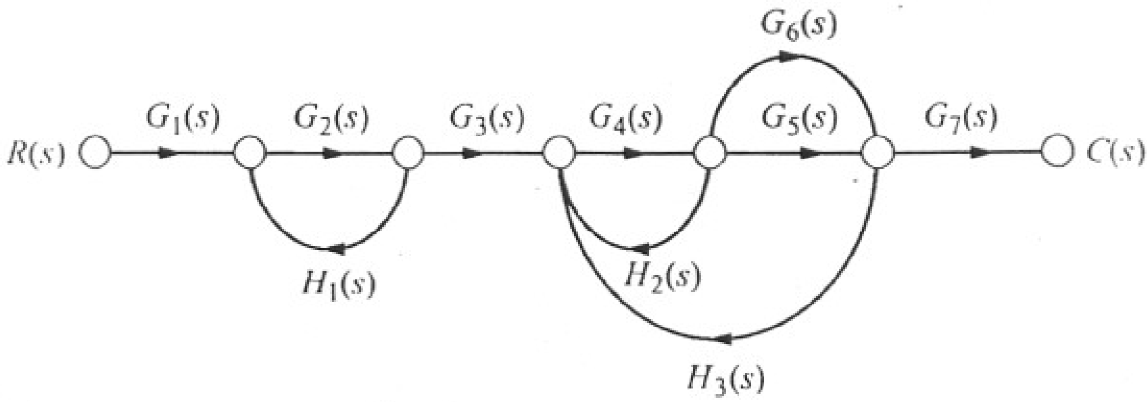

Figure 2

(25) Q2:
a) Draw a Nyquist Diagram of a system with the following open loop transfer function:

$$G(s) = \frac{1000}{s^3 + 41s^2 + 340s + 300}$$

Your answer should clearly show your derivations including the phase and gain equations, the Nyquist contour, and how the Nyquist diagram is drawn through mapping of key points.
b) Apply the Nyquist criterion to prove that this system is stable.
c) Indicate how you can obtain the gain and phase margins from the Nyquist Diagram.
d) Obtain the exact value of the gain margin for this system.

(25) Q3: Consider the open loop System represented by the following block diagram:

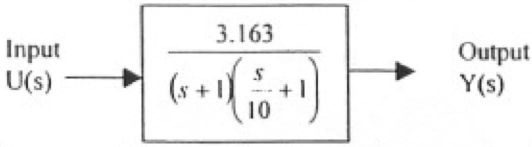

Figure 3

a) Use Bode diagrams to determine the gain and phase margins of the above system.
b) Design a proportional controller with unity feedback and, determine the maximum possible proportional gain that would provide a gain margin of <u>at least</u> 8 dB and a phase margin of <u>at least</u> 45 degrees.
c) For U(s)= $\frac{1}{s}$, what is the steady state error of the closed loop system obtained from b).
d) Determine the natural frequency and the damping ratio of the closed loop system obtained from b).
e) Indicate by using a block diagram how rate feedback can be used to achieve critical damping in the system obtained from b). Calculate the gain associated with this rate feedback.

(25) Q4: Use the Routh Hurowitz criterion to determine the number of roots in the left half-plane, the right half plane, and on the imaginary axis for the following characteristic equations:

a) $s^3+10s^2+31s+1030$
b) $s^5+2s^4+3s^3+6s^2+5s+3$
c) Explain the purpose and effect of each gain that is used in a Propotional-Integral-Derivative (PID) controller.
d) Use the Routh Hurowitz criterion and the Ziegler Nichols method to design a Proportional-Integral-Derivative (PID) controller for the system in Figure 4 (your answer should clearly indicate the structure of the transfer function associated with the PID controller).
e) Draw a block diagram representation of the system in Figure 4 with its PID controller.

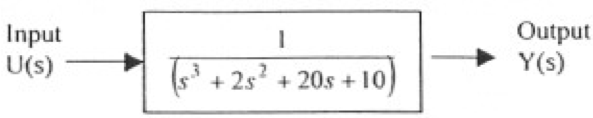

Figure 4

(25) Q5: Plot the Bode gain and phase diagrams for the following transfer functions:

a) $\frac{\left(\frac{s}{10}+1\right)}{(s+1)\left(\frac{s}{0.1}+1\right)}$

b) $\frac{10s^3}{(s+1)^2}$

c) $\frac{1}{(s^2+s+1)}$

d) $\frac{(s+100)}{(s+10)(s+1000)}$

e) $10s$