ME 431/AE411 Control Systems I
Midterm
October 1999

Time: 1 hour 30 minutes
Instructor: S. Habibi
Instructions: 1- Answer all 4 questions
2- Calculators are allowed
3- Students may bring up to 2 pages of letter-size notes
4- Question sheets are to be return with examination booklets

(30) Q1: An electromechanical system is shown:

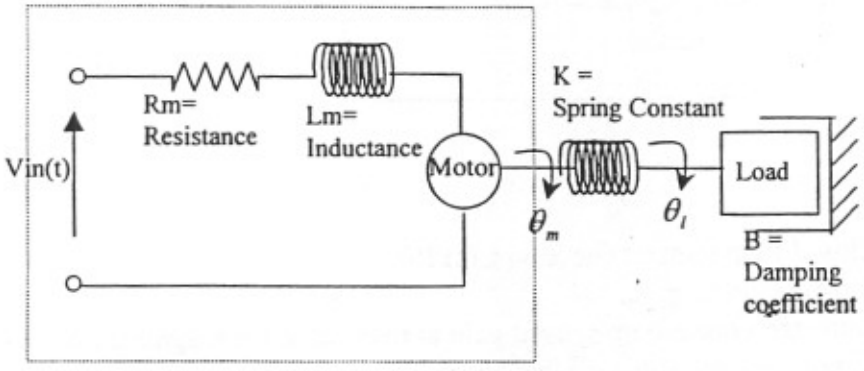
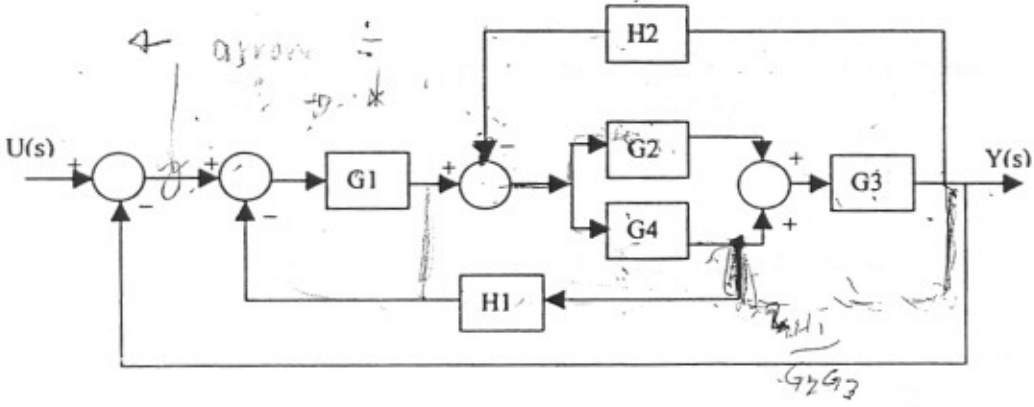


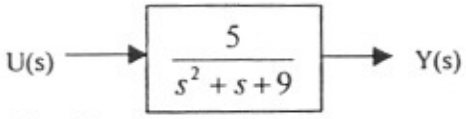
Figure 1

Constant Field DC Motor With
θ_m =motor angular position
θ_l =load angular position
Kt=motor torque constant
Ke= constant relating back emf to motor angular velocity.
Tm= motor torque
I= Current
(some formulas:
Tm=Kt * I;
Back emf= Ke * angular velocity)
Jm=Motor inertia
Jl=Load Inertia

a) Write the differential equations of the electromechanical system in Figure 1 and find their Laplace transform.
b) Draw a block diagram representation of the system in Figure 1.
c) Obtain the transfer function of the system represented by the following block diagram.



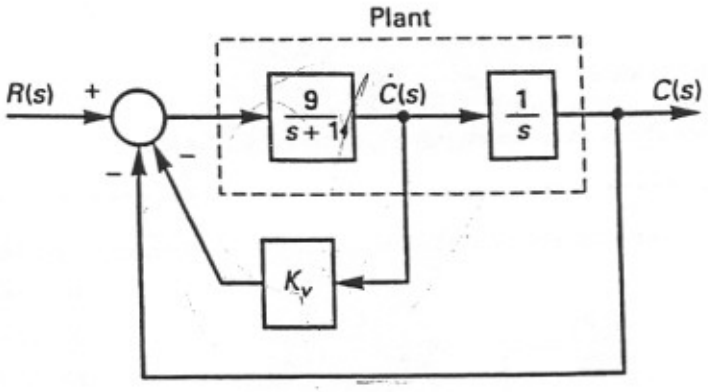
(20) Q2: Given a unit step input, sketch the time response of the following system:



show the value of:

- output at steady state,
- output at maximum overshoot,
- peak time, and
- settling time.

(30) 3. Consider the control system shown below:



(a) Determine the closed loop transfer function C(s)/R(s).
(b) Determine the closed loop dc gain.
(c) If $K_v = 0$, determine the closed loop system gain at resonance (or magnitude of the closed loop frequency response at resonance).
(d) What is the resonant frequency for $K_v = 0$?
(e) A design specification is that the peak closed loop gain can be no greater than 1.30 at any frequency and this results in a damping ratio of $\xi = 0.425$. Determine the value of K_v such that this specification is satisfied.

(Some formulas: $\omega_r T_p = \dfrac{\pi}{\sqrt{1-\xi^2}}$; $M_{p\omega} = |G(j\omega_r)| = \dfrac{1}{2\xi\sqrt{1-\xi^2}}$)

(15) 4. Comment on the stability of each of the following:

(a) $T(s) = \dfrac{s+2}{(s^3 + 2s^2 + s)}$

(b) $T(s) = \dfrac{10}{s^2 - 9}$

(c) $T(s) = \dfrac{6(s-1)}{(s+1)(s+2)(s+3)}$

THE END