UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2011/2012

NAME OF COURSE	:	CONTROL SYSTEM DESIGN
COURSE CODE	:	BDA 4023
PROGRAM	:	BACHELOR OF MECHANICAL ENGINEERING WITH HONOURS
DATE OF EXAMINATION	:	JUNE 2012
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER ANY **FOUR (4)** QUESTIONS

THIS PAPER CONSISTS OF SIX (6) PAGES

Q1 a) Briefly explain the purpose of representing state space vector in dynamic systems.

(5 marks)

b) **Figure Q1** shows a spring-mass-damper system where k_1 and k_2 are the spring coefficients, and c_1 is a damping coefficient of the system. The system is given with u, an external force acting on system; $m_1$and m_2 are mass of carts, and p and q are position of carts.

i) Derive all equations related to this system.

ii) Draw the block diagram related to part (i).

ii) From equations derived in part i), determine the matrix A and matrix B using state space methods. Obtain the transfer function of the system.

(20 marks)

Q2 Consider the control system shown in **Figure Q2.** The open loop transfer function of a system is given as, $G(s) = \dfrac{1}{s(s+2)(s+5)}$

Assume the compensator, $G_c(s)$ is a simple proportional controller K, obtain all pertinent pints for root locus and sketch the root locus on a linear graph paper.

i) Determine the location of the dominants poles to have critically damped response, and find the time constant corresponding to this location.

ii) Also determine the value of K and the corresponding time constant for dominant poles damping ratio of 0.707.

iii) If $G_c(s)$ is a phase lead compensator, design the compensator for the following time-domain specifications:

-Dominant poles damping ratio ζ=0.707 and dominant poles time constant τ=0.5 seconds.

(25 marks)

Q3 **a)** The control system of jet printer valve has open loop transfer function as follows:

$$KGH(s) = \frac{K}{(s+70)s}$$

Design an appropriate state variable feedback system for $r(t)=-k_1x_1-k_2x_2$. The velocity error constant K_v to be 35 and the overshoot to a step to be approximately 4% so that damping ratio is 0.707. The settling time (with a 2% criterion) desired is 0.11 second.

(12 marks)

b) A process has the transfer function:

$$\dot{x}=\begin{bmatrix}-10 & 0\\ 1 & 0\end{bmatrix}x+\begin{pmatrix}1\\0\end{pmatrix}u$$

$$y=[0 \quad 1]x + [0]u$$

i) Determine the state variable feedback gains to achieve a settling time (with a 2% criterion) of 1 second and an overshoot of about 10%.

ii) Sketch the block diagram of the resulting system.

(13 marks)

Q4 (a) Draw the integrated full-state feedback and observer block diagram. From this diagram prove that the equation of feedback law and observer yields the compensator system is given by:

$$\hat{\dot{x}}=(\mathbf{A}-\mathbf{BK}-\mathbf{LC})\hat{x} + \mathbf{L}y$$

$$u=-\mathbf{K}$$

(12 marks)

(b) Consider the system represented in state variable form:

$$\dot{x}=\begin{bmatrix}1 & 2\\ -6 & -12\end{bmatrix}x+\begin{pmatrix}-5\\1\end{pmatrix}u$$

$$y=[4 \quad -3]x + [0]u$$

i) Verify the system is observable and controllable.

ii) Design the full state feedback law using Ackerman's method if $s_{1,2}$=-1±j.

iii) Design an observer by placing the closed loop system poles at $s_{1,2}$=-12.

(13 marks)

Q5 a) i) What is a digital signal?

ii) Draw the location of its poles in the z-plane.

(6 marks)

b) i) What is an anti-alaising filter?

ii) State the sampling theorem and describe the effects of alaising on a sampled signal.

(6 marks)

c) The following transfer function is a lag network designed to introduce a gain attenuation of 10 (-20 dB) at ω=3 rad/sec:

$$G(s) = \frac{10s+1}{(100s+1)}$$

(i) Assume a sampling period of T=0.25 sec, and compute and plot in the z-plane the pole and zero locations of the digital implementations of *H(s)* obtained using pole-zero mapping.

(ii) For the equivalent digital systems in part (i), plot the Bode magnitude curves over the frequency range ω=0.01 to 10 rad/sec.

(13 marks)

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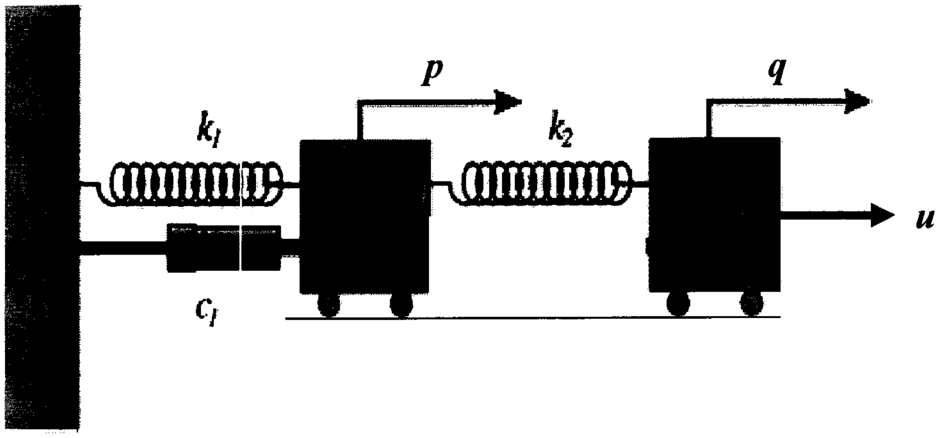

Figure Q1

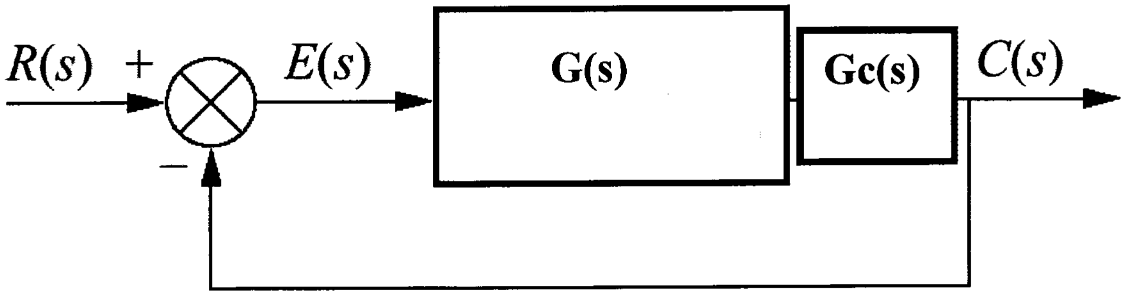

Figure Q2

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Table Q5: Some Common z-Transform

Sequence	Transform	ROC
1. $\delta[n]$	1	All z
2. $u[n]$	$\dfrac{1}{1-z^{-1}}$	$\lvert z\rvert > 1$
3. $-u[-n-1]$	$\dfrac{1}{1-z^{-1}}$	$\lvert z\rvert < 1$
4. $\delta[n-m]$	z^{-m}	All z except 0 (if $m > 0$) or ∞ (if $m < 0$)
5. $a^n u[n]$	$\dfrac{1}{1-az^{-1}}$	$\lvert z\rvert > \lvert a\rvert$
6. $-a^n u[-n-1]$	$\dfrac{1}{1-az^{-1}}$	$\lvert z\rvert < \lvert a\rvert$
7. $na^n u[n]$	$\dfrac{az^{-1}}{(1-az^{-1})^2}$	$\lvert z\rvert > \lvert a\rvert$
8. $-na^n u[-n-1]$	$\dfrac{az^{-1}}{(1-az^{-1})^2}$	$\lvert z\rvert < \lvert a\rvert$
9. $\cos(\omega_0 n)u[n]$	$\dfrac{1-\cos(\omega_0)z^{-1}}{1-2\cos(\omega_0)z^{-1}+z^{-2}}$	$\lvert z\rvert > 1$
10. $\sin(\omega_0 n)u[n]$	$\dfrac{\sin(\omega_0)z^{-1}}{1-2\cos(\omega_0)z^{-1}+z^{-2}}$	$\lvert z\rvert > 1$
11. $r^n\cos(\omega_0 n)u[n]$	$\dfrac{1-r\cos(\omega_0)z^{-1}}{1-2r\cos(\omega_0)z^{-1}+r^2z^{-2}}$	$\lvert z\rvert > r$
12. $r^n\sin(\omega_0 n)u[n]$	$\dfrac{r\sin(\omega_0)z^{-1}}{1-2r\cos(\omega_0)z^{-1}+r^2z^{-2}}$	$\lvert z\rvert > r$
13. $\begin{cases} a^n, & 0 \le n \le N-1, \\ 0, & \text{otherwise} \end{cases}$	$\dfrac{1-a^N z^{-N}}{1-az^{-1}}$	$\lvert z\rvert > 0$