UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
DEPARTMENT OF ELECTRONIC ENGINEERING

MAIN EXAMINATION DECEMBER 2008

TITLE OF PAPER: **ADVANCED CONTROL SYSTEMS**

COURSE CODE: **EIN530**

TIME ALLOWED: **THREE** HOURS

INSTRUCTIONS:

1. Answer **question 1** and any other three (3) questions.
2. Each question carries 25 marks.
3. Marks for different sections are shown in the right-hand margin.

This paper has 7 pages including this page.

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Partial Table of z- and s-Transforms

	f(t)	F(s)	F(z)	f(kt)
	$u(t)$	$\frac{1}{s}$	$\frac{z}{z-1}$	$u(kT)$
	t	$\frac{1}{s^2}$	$\frac{Tz}{(z-1)^2}$	kT
	t^n	$\frac{n!}{s^{n+1}}$	$\lim_{a\to 0}(-1)^n \frac{d^n}{da^n}\left[\frac{z}{z-e^{-aT}}\right]$	$(kT)^n$
	e^{-at}	$\frac{1}{s+a}$	$\frac{z}{z-e^{-aT}}$	e^{-akT}
5.	$t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$	$(-1)^n \frac{d^n}{da^n}\left[\frac{z}{z-e^{-aT}}\right]$	$(kT)^n e^{-akT}$
6.	$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$	$\frac{z \sin \omega T}{z^2 - 2z\cos\omega T + 1}$	$\sin \omega kT$
7.	$\cos \omega t$	$\frac{s}{s^2+\omega^2}$	$\frac{z(z-\cos\omega T)}{z^2 - 2z\cos\omega T + 1}$	$\cos \omega kT$
8.	$e^{-at}\sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$	$\frac{ze^{-aT}\sin\omega T}{z^2 - 2ze^{-aT}\cos\omega T + e^{-2aT}}$	$e^{-akT}\sin \omega kT$
9.	$e^{-at}\cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$	$\frac{z^2 - ze^{-aT}\cos\omega T}{z^2 - 2ze^{-aT}\cos\omega T + e^{-2aT}}$	$e^{-akT}\cos \omega kT$
10.			$\frac{z}{z+a}$	$a^k \cos k\pi$

z-Transform Theorems

	Theorem	Name
1.	$z\{af(t)\} = aF(z)$	Linearity theorem
2.	$z\{f_1(t) + f_2(t)\} = F_1(z) + F_2(z)$	Linearity theorem
3.	$z\{e^{-at}f(t)\} = F(e^{aT}z)$	Complex differentiation
4.	$z\{f(t-nT)\} = z^{-n}F(z)$	Real translation
5.	$z\{tf(t)\} = -Tz\frac{dF(z)}{dz}$	Complex differentiation
6.	$f(0) \doteq \lim_{z\to\infty} F(z)$	Initial value theorem
7.	$f(\infty) = \lim_{z\to 1}(1-z^{-1})F(z)$	Final value theorem

Question 1

(a) State the definition of **adaptive control**? [3 marks]

(b) Outline the design procedure for a state variable compensator with integrated full-state feedback and observer.

[10 marks]

(c) Outline the design procedure for a phase- lead compensation network using the root - locus method.

[12 marks]

Question 2

Determine an internal model controller $G_C(s)$ for the system shown in Figure 2. It is desired that the steady-state error to a step input be zero, the settling time (with a 2% criterion) be 2 seconds. and the maximum percent overshoot be 16.3 %.

[25 marks]

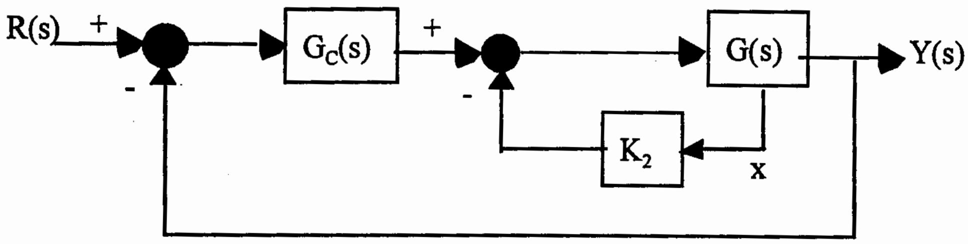

Figure 2

Where the plant $G(s) = \dfrac{1}{(s+1)(s+2)}$

Question 3

A chemical reactor process whose production rate is a function of catalyst addition is shown in Figure 3. Design a compensator $G_c(s)$ by using Bode diagram method so that the system should have a steady-state error less than 0.1A for a step input, r(t) = A, and a phase margin greater than 64^0.

[25 marks]

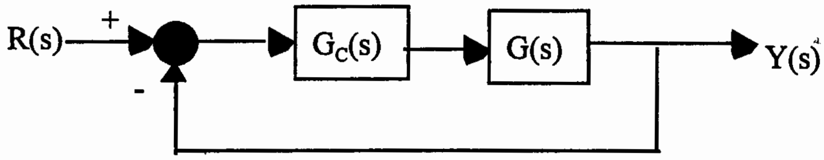

Figure 2

where $$G(s) = \frac{e^{-50s}}{(40s+1)^2}$$

Question 4

(a) The following difference equation algorithm

$$u(k) = 11.75x(k) - 6.25x(k-1) + 0.5u(k-1); \qquad (T = 1).$$

for a PID controller can be implemented using a microprocessor. We would like to implement this PID controller in s-domain, therefore, obtain the transfer function $G_C(s)$ and the values of the proportional gain, reset time, and derivative time.

[16 marks]

(b) For the **deadbeat** system shown in Figure 4, design a controller D(z) so that the steady-state error to a step input is zero. [9 marks]

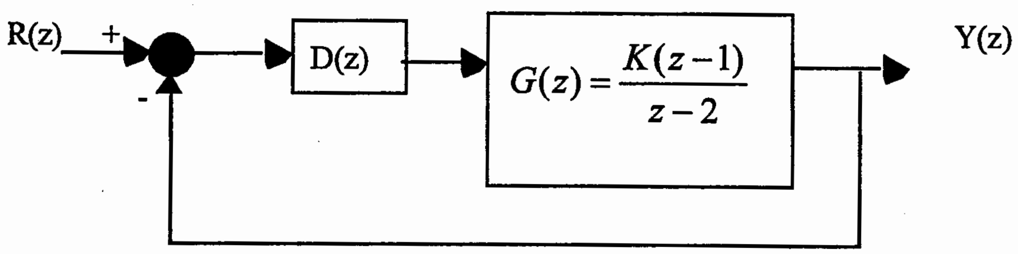

Figure 4

Question 5

The electric motor drive for a railway vehicle is shown in figure 5. The power amplifier is nonlinear and can be approximated by $v_2 = 2e^{3v_1}$

Assume the normal operating point of the power amplifier is $v_{10} = 1$

(a) obtain a linear model of this system [7 marks]

(b) determine the response when the desired velocity is 10 rad/sec and calculate the steady-state error, maximum percent overshoot and settling time.

[18 marks]

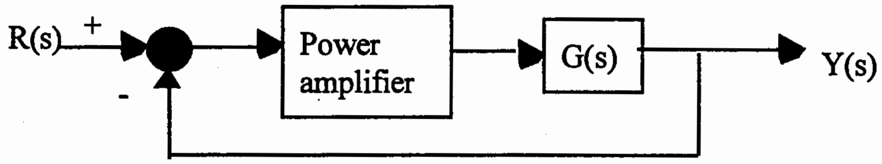

Figure 5

Where R(s) is the desired velocity
Y(s) is the vehicle velocity
G(s) is the transfer function of the armature controlled motor

$$G(s) = \frac{5}{s^2 + 1.25s + 0.75}$$

SEMI-LOG PAPER (5 CYCLES x 1/10")

Five Cycle Semi-Log

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