UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
DEPARTMENT OF ELECTRONIC ENGINEERING

MAIN EXAMINATION December 2006

TITLE OF PAPER : **CONTROL SYSTEMS I**

COURSE NUMBER : **E430**

TIME ALLOWED : THREE HOURS

INSTRUCTIONS :ANSWER **QUESTION 1** AND ANY OTHER **THREE QUESTIONS**

QUESTION 1 CARRIES 40 MARKS

QUESTION 2, 3, 4, AND 5 CARRY 20 MARKS EACH.

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)
1.	$u(t)$	$\frac{1}{s}$	$\frac{z}{z-1}$	$u(kT)$
2.	t	$\frac{1}{s^2}$	$\frac{Tz}{(z-1)^2}$	kT
3.	t^n	$\frac{n!}{s^{n+1}}$	$\lim_{a\to 0}(-1)^n \frac{d^n}{da^n}\left[\frac{z}{z-e^{-aT}}\right]$	$(kT)^n$
4.	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

Note: kT may be substituted for t in the table.

Question 1

A) A laser printer uses a laser beam to print copy rapidly for a computer. The laser is positioned by a control input, *r(t)* which is the desired position of the laser beam.

$$Y(s) = \frac{5(s+100)}{s^2 + 60s + 500} R(s).$$

(I) If *r(t)* is a unit step input find the output *y(t)*. [6 marks]
(II) What is the final value of *y(t)*? [2 marks]
(III)What is the rise time of *y(t)*? [8 marks]

B) Use the input feed-forward format to determine a state space representation for a system with the transfer function

$$\frac{Y(s)}{R(s)} = \frac{(s+10)^2}{s^4 + 12s^3 + 23s^2 + 34s + 40}$$ [12 marks]

C) A feedback control system has a process transfer function $G(s) = \dfrac{K(s+40)}{s(s+10)}$

and a feedback transfer function $H(s) = \dfrac{1}{s+20}$

(I) Determine the limiting value of gain K for a stable system. [6 marks]
(II) For the gain K that results in marginal stability system, determine the magnitude of the imaginary roots. [2 marks]
(III) Determine the steady state error. [4 marks]

Question 2

A unity feedback system has $GH(s) = \dfrac{K(s+10)}{(s+2)(s+5)}$

Find

A) the breakaway points on the real axis and the gain K for this point, [6 marks]
B) the gain and the roots when two roots lie on the imaginary axis. [7 marks]
C) Sketch the root locus. [7 marks]

Question 3

Consider a system as shown below in Figure 3 with a zero-order hold, a plant

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

and T=1 seconds.

A) (I) Let D(Z) = K and determine the transfer function G(s)D(z). [6 marks]

(II) Calculate the maximum value of K for a stable system. [8 marks]

B) Determine D(z) from $G_c(s) = 100\frac{s+50}{s+100}$ when T=0.01 seconds [6 marks]

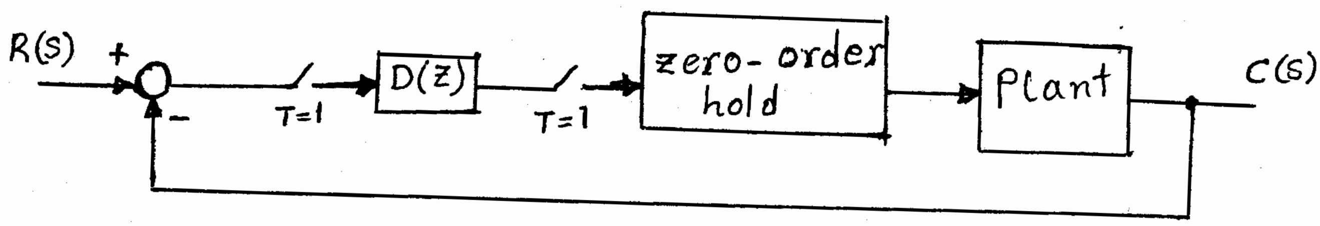
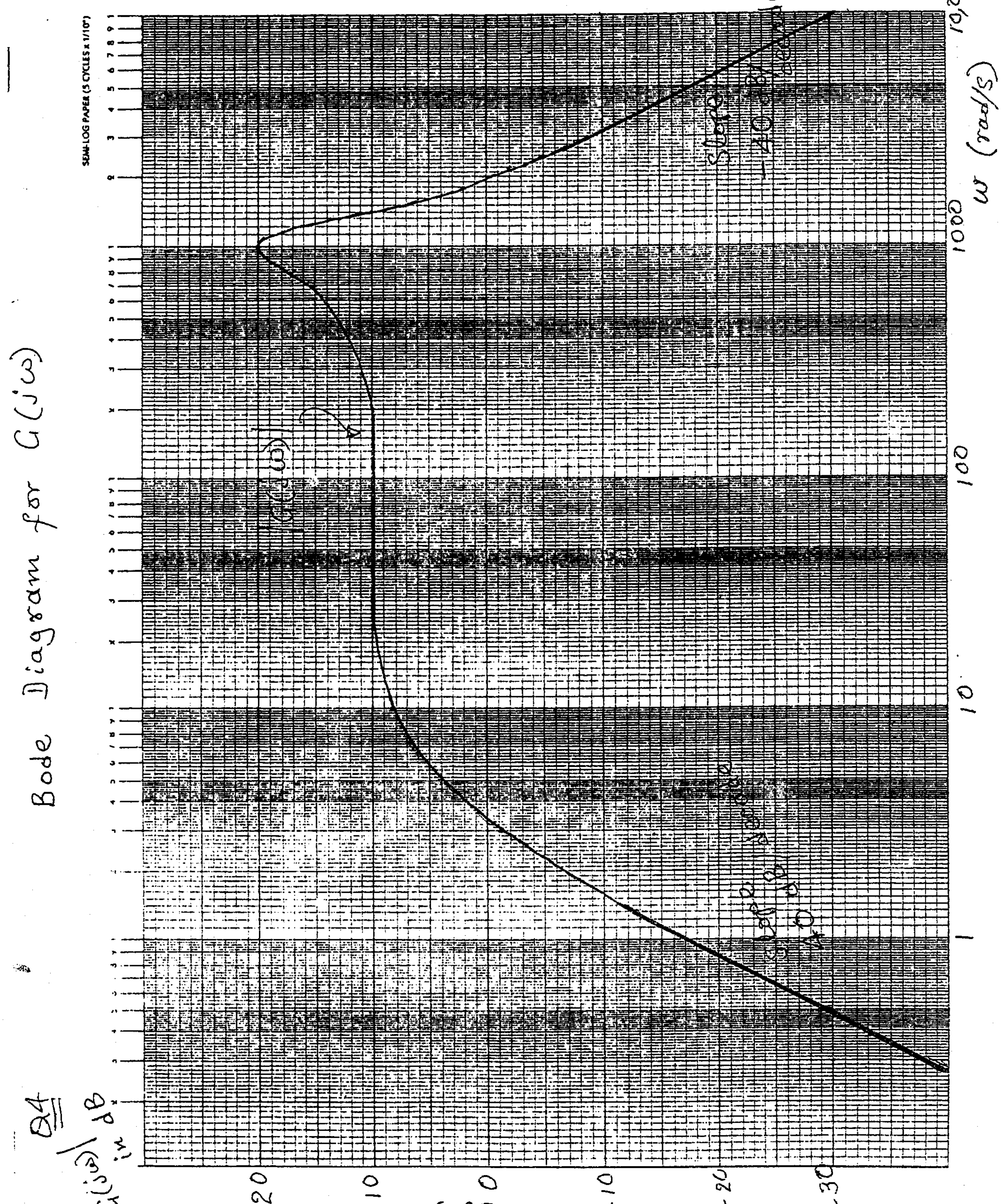


Figure 3

Question 4

Determine the transfer function G(s), bandwidth and gain cross-over frequency from the Bode diagram shown below.

[20 marks]



Question 5

A) When is phase-lag compensation not applicable? [3 marks]

B) What are the two disadvantages of phase-lead compensation? [6 marks]

C)Why are pneumatic controllers popular in industry? [3 marks]

D) Write down the equation for a PID controller and define all the necessary terms and constants [8 marks]