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UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRONIC ENGINEERING

MAIN EXAMINATION 2005

TITLE OF PAPER: **CONTROL SYSTEMS**

COURSE NUMBER: **E430**

TIME ALLOWED: THREE HOURS

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

QUESTION 1 CARRIES 40 MARKS

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

MARKS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT-HAND MARGIN

THIS PAPER HAS 8 PAGES, INCLUDING THIS PAGE

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APPENDIX

H z-Transform Pairs

Table H.1

$x(t)$	$X(s)$	$X(z)$
1. $\delta(t) = \begin{cases} 1 & t=0, \\ 0 & t=kT, k \neq 0 \end{cases}$	1	1
2. $\delta(t-kT) = \begin{cases} 1 & t=kT, \\ 0 & t \neq kT \end{cases}$	e^{-kTs}	z^{-k}
3. $u(t)$, unit step	$1/s$	$\frac{z}{z-1}$
4. t	$1/s^2$	$\frac{Tz}{(z-1)^2}$
5. t^2	$2/s^3$	$\frac{T^2z(z+1)}{(z-1)^3}$
6. e^{-at}	$\frac{1}{s+a}$	$\frac{z}{z-e^{-aT}}$
7. $1-e^{-at}$	$\frac{a}{s(s+a)}$	$\frac{(1-e^{-aT})z}{(z-1)(z-e^{-aT})}$
8. te^{-at}	$\frac{1}{(s+a)^2}$	$\frac{Tze^{-aT}}{(z-e^{-aT})^2}$
9. t^2e^{-at}	$\frac{2}{(s+a)^3}$	$\frac{T^2e^{-aT}z(z+e^{-aT})}{(z-e^{-aT})^3}$
10. $be^{-bt}-ae^{-at}$	$\frac{(b-a)s}{(s+a)(s+b)}$	$\frac{z[z(b-a)-(be^{-aT}-ae^{-bT})]}{(z-e^{-aT})(z-e^{-bT})}$
11. $\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$	$\frac{z \sin \omega T}{z^2-2z\cos \omega T+1}$
12. $\cos \omega t$	$\frac{s}{s^2+\omega^2}$	$\frac{z(z-\cos \omega T)}{z^2-2z\cos \omega T+1}$
13. $e^{-at}\sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$	$\frac{(ze^{-aT}\sin \omega T)}{z^2-2ze^{-aT}\cos \omega T+e^{-2aT}}$

Question 1

A. Given a control system with a proportional controller of which the controller gain is 2.8, the controller output range from 0% to 100% is 4 mA to 20 mA, the final control element is set at 50%, a sudden change of the load causes an error signal change of 0.5 Volts and the error range is 10 volts (± 5 V).

(I) Find the actual controller output (in mA) at 50% set point. (7 marks)

(II) Find the input signal range required to cause the output to swing from 0% to 100%

(3 marks)

B. When we use quantitative mathematical models of physical systems to design and analyze control systems, the relationship between system variable must be analyzed . So, determine the state variable matrix equation for the system shown in Figure 1.

[Let $x_1 = v_1$, $x_2 = v_2$, and $x_3 = i$. Input signal v_i and i_s should appear as they are.]

(10 marks)

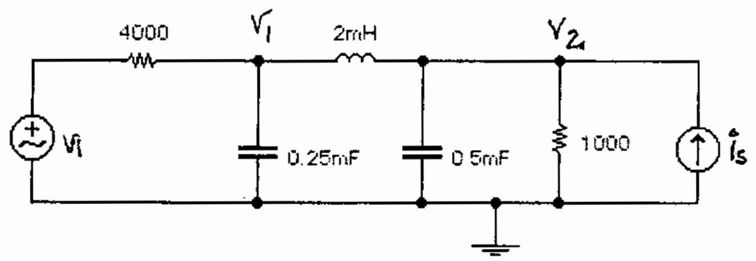

Figure 1 B

C. A system has a damping ratio of $\frac{1}{\sqrt{2}}$, a natural frequency of 81 rad/sec and a dc gain of 4. Find the response of the system to a unit step input. (10 marks)

D. Obtain the steady-state error for the closed-loop sampled system shown in figure 1 D under the following test signals inputs

(I) unit step

(II) unit ramp

(III) unit parabolic (10 mark)

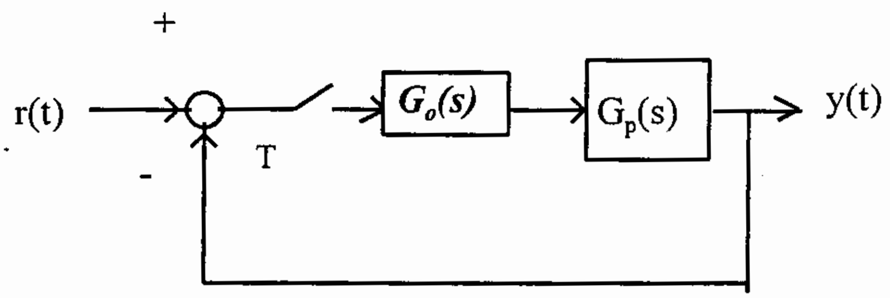

Figure 1 D

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

$$G_o(s) = \frac{1-e^{-Ts}}{s}$$

Question 2

It is desirable to use well-designed controllers to maintain building temperature with solar collector space-heating systems. One solar heating system can be described by

$$\frac{dx_1(t)}{dt} = 3x_1(t) + u(t)$$

$$\frac{dx_2(t)}{dt} = 2x_2 + u(t) + d(t)$$

where **$x_1(t)$** is the temperature deviation from desired equilibrium

$x_2(t)$ is the temperature of the storage material such as a water tank

$u(t)$ is the rate of solar heat

$d(t)$ is the solar disturbance on the storage temperature such as overcast skies

with **$u(t)$** = 0.8, **$d(t)$** = 1 and assuming zero initial conditions,

(A) write the system matrix equations (6 marks)

(B) solve for **$x_1(t)$** and **$x_2(t)$** (14 marks)

Question 3

An ES 151 Educational servo system is to be used in a position control experiment to investigate the open loop time constant. The connection are as shown in Figure 3.
For this system obtain

(A) the transfer function $\frac{\theta_o}{\theta_i}$ (5 marks)

(B) the differential equation describing this system (3 marks)

(C) the equations natural underdamped frequency and damping ratio and the values of the natural frequency and damping ration when k = 80 revolutions/minute/volt, k_{pot} = 0.1volt/degree) and τ = 0.25 seconds. . (12 marks)

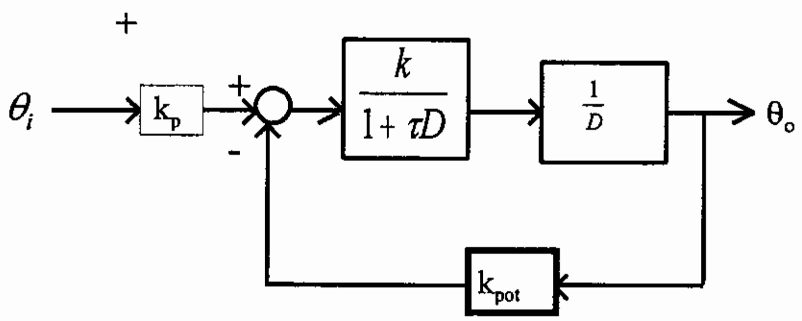

Figure 3

Question 4

A new, suspended, mobile, remote-controlled system to bring three-dimensional mobility to professional African League of Nations Football has a camera that can move over the field as well as up and down. The motor control on each pulley is represented by Figure 4 with

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

We wish to achieve a phase margin of 45^0 using $G_c(s)$. Determine

A) the phase margin of the uncompensated system (8 marks)

B) a suitable crossover frequency (4 marks)

C) the digital controller D(z) with a sampling time of $T = 0.001$ seconds (8 marks)

Question 5

A unity feedback system has $KG(s) = \dfrac{K(s+2)}{s(s+1)}$.

A) Find the breakaway and entry points on the real axis if the two points exit. (6 marks)

B)Find the gain and the roots when the real part of the complex roots is located at -2 (4 marks)

C) Sketch the root locus (10 marks)

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