KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE

(ENERGY ENGINEERING)

SET 410: SYSTEMS & CONTROL ENGINEERING

DATE: WEDNESDAY, 11TH APRIL 2012 **TIME: 2.00 P.M. – 4.00 P.M.**

INSTRUCTIONS

Answer any three (3) questions
All questions carry equal (20) marks each
Answer books, special graph paper provided

Q1 (a) The diagram figure (a) represents a position control system. Calculate:

(i) The steady state error due to a load L = 3
(ii) The following error due to a ramp input with a slope of 0.1 rad/s

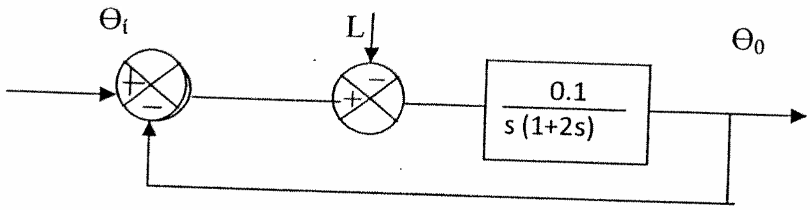

Figure Q.1(a)

(6 m

(b) Water enters a tank at the top and leaves through an orifice at the bottom. Deduce a transfer function relating the depth to the inflow. Use a straight-line approximation for the relation between outflow and the liquid depth of the tank.

From it find:

(i) The time constant
(ii) The steady-state value

(c) A unit feedback position control system has a forward path transfer function

$$G(s) = K/[s(1+s\tau 1)(1+s\tau 2)$$

Find
(i) The closed loop transfer function and
(ii) For a ramp input Vt, find the following error

(d) A thermometer has time constant $\lambda = 2$ seconds. When reading 15^0 c it is placed in hot water and the reading rises to a steady value of 78^0 c. Estimate when it reads $45\,^0$c

Q.2. a) A second order system is represented by $\ddot{y} + 3\dot{y} + 2y = \dot{x} + 2x$, where x is input, y is output and $x(0) = x_0$, $\dot{y}(0) = y(0) = 0$.
If $x(t) = e^{-3t}$ is the input, determine the response y(t).

(4 mrks)

b) Draw a block diagram for the model of a mechanical system represented by figure Q.2. (b). Then simplify the block diagram and obtain the transfer function $X_0(s) / X_i(s)$. Assume that the displacement X_0 is measured from equilibrium position when $X_i = 0$

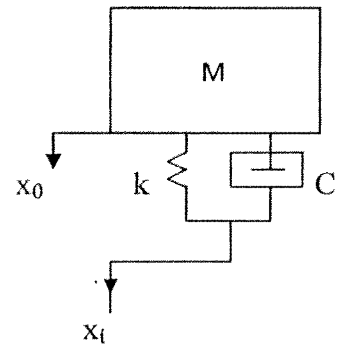

Figure Q.2 (b)

(6 mrks)

c) Assuming the system in figure Q.2 (c) is linear determine the output C (s)

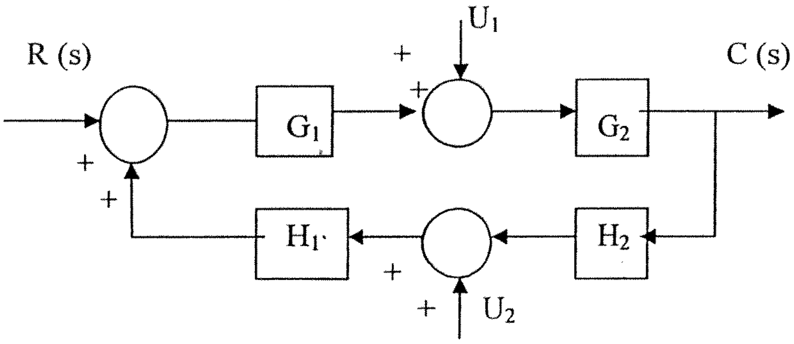

Figure Q.2 (c)

(6 mrks)

d) Develop the system transfer function $E_0(s) / E_i(s)$ for an RC circuit shown in figure Q.2 (d).

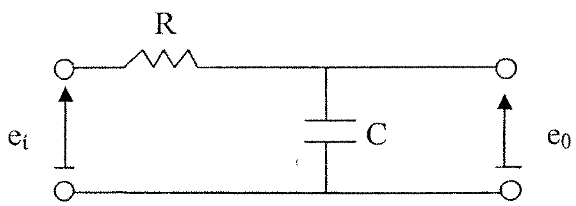

Figure Q.2 (d)

(4 mrks)

Q.4. a) Define system stability in terms of:-

(i) The system's impulse response

(ii) Input – output relationship

(iii) System's eigenvalues and the complex plane

(3 mrks)

b) (i) Show how the stability of an nth order system can be determined using Routh's stability criterion **(3 mrks)**

(ii) The transfer function of control element is given by $K / (s^3 + 4s^2 + 11s)$ This element is connected in a unity feedback circuit. Calculate the minimum positive value of K at which the system becomes unstable

(3 mrks)

(iii) Given that K = 8 and s = -1 is a root of the characteristic equation, determine the response of the feedback system to a unit step input,

(3 mrks)

c) A feedback control system has an open-loop transfer function

$$\frac{50}{s(1 + 0.1s)(1 + 0.5s)}$$

i) Prepare the Nyquist diagram and hence

ii) Determine the phase and Gain margins

iii) Deduce from these values whether the system is stable, stating the reasons for your answer.

(8 mrks)

Q.5. a) What are the nine rules used in root-locus plot

(5 mrks)

b) Consider a control system with $G(s) = \frac{K(s+2)}{s^2 + 2s + 3}$, $H(s) = 1$

) sketch the root locus

(6 mrks)

c) Prepare a bode diagram for the open-loop transfer function

$$G(s) = \frac{5}{s(1 + 0.6s)(1 + 0.1s)}$$

and determine:-

(i) The Phase margin

(ii) The gain margin

(iii) Draw the diagram

(9 **mrks)**

Q.3. a) Define the following terms used in control systems engineering:-

(i) system
(ii) control
(iii) Feedback
(iv) Distinguish between open loop and closed loops systems.

(4 mrks)

b) Briefly discuss, with the aid of sketches the details of any three types of standard test input signals used in the analysis of the dynamic behavior of a control system.

(3 mrks)

c) For the system shown in figure Q.3 (c) where $0<\zeta<1$ determine:-

(i) the time response
(ii) the error response
(iii) The steady state error, when the system is subjected to a step input.

(6 mrks)

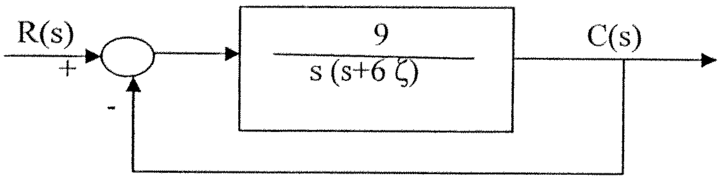

Figure Q.3 (c)

d) For the system in figure Q 3 (d), find, for a unit step input:-

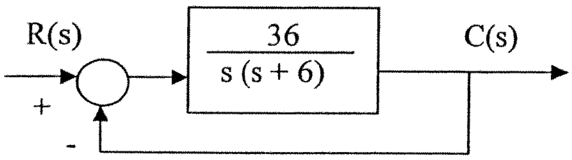

Figure Q.3 (d)

(i) The time response
(ii) The rise time
(iii) The peak time
(iv) Maximum overshoot
(v) The settling time.

(7 mrks)

FORM PAIRS FOR CONTROL ANALYSIS

$F(s)$	$f(t) \quad t > 0$
$\dfrac{1}{s^2 + 2\zeta\omega_n s + \omega_n^2}$	$\dfrac{1}{\omega_d} e^{-\zeta\omega_n t} \sin \omega_d t \qquad \omega_d \equiv \omega_n\sqrt{1-\zeta^2}$
$\dfrac{s+a}{(s+a)^2+\omega^2}$	$e^{-at}\cos\omega t$
$\dfrac{s+z_1}{(s+a)^2+\omega^2}$	$\sqrt{\dfrac{(z_1-a)^2+\omega^2}{\omega^2}}\, e^{-at}\sin(\omega t+\phi) \qquad \phi \equiv \tan^{-1}\left(\dfrac{\omega}{z_1-a}\right)$
$\dfrac{1}{s}$	$1(t)$ unit step
$\dfrac{1}{s}e^{-Ts}$	$1(t-T)$ delayed step
$\dfrac{1}{s}(1-e^{-Ts})$	$1(t)-1(t-T)$ rectangular pulse
$\dfrac{1}{s(s+a)}$	$\dfrac{1}{a}(1-e^{-at})$
$\dfrac{1}{s(s+a)(s+b)}$	$\dfrac{1}{ab}\left(1-\dfrac{be^{-at}}{b-a}+\dfrac{ae^{-bt}}{b-a}\right)$
$\dfrac{s+z_1}{s(s+a)(s+b)}$	$\dfrac{1}{ab}\left(z_1-\dfrac{b(z_1-a)e^{-at}}{b-a}+\dfrac{a(z_1-b)e^{-bt}}{b-a}\right)$
$\dfrac{1}{s(s^2+\omega^2)}$	$\dfrac{1}{\omega^2}(1-\cos\omega t)$
$\dfrac{s+z_1}{s(s^2+\omega^2)}$	$\dfrac{z_1}{\omega^2}-\sqrt{\dfrac{z_1^2+\omega^2}{\omega^4}}\cos(\omega t+\phi) \qquad \phi \equiv \tan^{-1}(\omega/z_1)$
$\dfrac{1}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$	$\dfrac{1}{\omega_n^2}-\dfrac{1}{\omega_n\omega_d}e^{-\zeta\omega_n t}\sin(\omega_d t+\phi)$ $\omega_d \equiv \omega_n\sqrt{1-\zeta^2} \qquad \phi \equiv \cos^{-1}\zeta$
$\dfrac{1}{s(s+a)^2}$	$\dfrac{1}{a^2}(1-e^{-at}-ate^{-at})$
$\dfrac{s+z_1}{s(s+a)^2}$	$\dfrac{1}{a^2}[z_1-z_1e^{-at}+a(a-z_1)te^{-at}]$
$\dfrac{1}{s^2}$	t unit ramp
$\dfrac{1}{s^2(s+a)}$	$\dfrac{1}{a^2}(at-1+e^{-at})$
$1 \quad n = 1,2,3,\ldots$	$\dfrac{t^{n-1}}{(n-1)!} \qquad 0! = 1$

****