TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology
Department of Electrical & Electronics engineering
UNIVERSITY EXAMINATION FOR:
HIGHER DIPLOMA IN TECHNOLOGY
ECI 3201 : Process Control and Automation I
END OF SEMESTER EXAMINATION
SERIES: APRIL 2016
TIME: 2 HOURS
DATE: 15 Apr 2016

Instructions to Candidates
You should have the following for this examination

- *Answer booklet*
- *Non-Programmable scientific calculator*

This paper consists of **FIVE** questions. Attempt any **THREE** questions.
Maximum marks for each part of a question are as shown.
Do not write on the question paper.

Question ONE

a. Draw a block-diagram of a typical negative-feedback, closed-loop system, labelling the individual blocks and the system inputs and outputs. State two advantages and two disadvantages of closed-loop systems when compared to open-loop systems. **(7 marks)**

b. Figure Q1 shows a process which is being controlled in a closed-loop system with unity feedback. The process can be modelled using a first-order model with system gain, *K*, and a system time constant, *τ*. **(13 marks)**

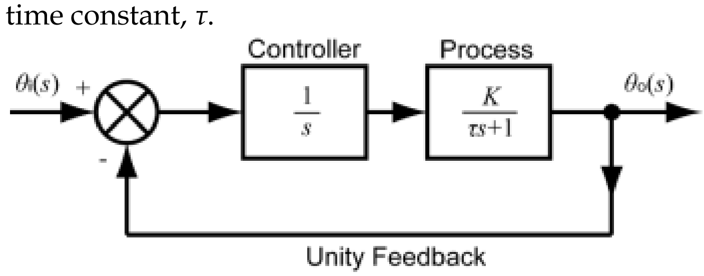

Figure Q1

i. Obtain the expression for the forward-path transfer function for the system, $G_o(s)$.
ii. Determine the system type number.
iii. Obtain the expression for the closed-loop transfer function for the system, *G(s)*.

iv. If this system was subject to a unit step reference input, what would be the steady-state error value? Use your knowledge of system types, controller effects or the final value theorem.

v. If the system time constant, τ is 0.1 seconds and the system gain K is 2.5, will the closed-loop system be underdamped, critically damped or over-damped?

Question TWO

a. Figure Q2 shows the block diagram for a system which has two subsystem blocks on the feed-forward path and two subsystem blocks on the negative feedback path. Derive an expression for the output response $\theta_O(s)$ in terms of the reference input $\theta_i(s)$ and the two disturbance inputs $\theta_{d1}(s)$ and $\theta_{d2}(s)$. **(5 marks)**

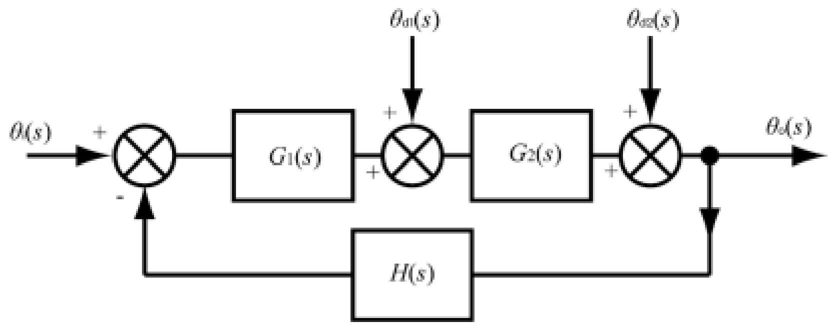

Figure Q2

b. State Routh-Hurwitz criteria for stability. **(3 marks)**

c. State any THREE limitations of using Hurwitz criteria for determining stability of a system. **(6 marks)**

d. Determine whether the system is stable whose characteristic equation is given as shown below, **(6 marks)**

$$s^4 + 2s^3 + 3s^2 + 4s + 5 = 0$$

Question THREE

a. Most controllers used in industry are the *three term* or *PID controllers*. PID stands for:

- **P**roportional term in the controller.
- **I**ntegral term in the controller.
- **D**erivative term in the controller.

Describe the control action of each term in the controller and define their mathematical model. **(6 marks)**

b. It is found that the behavior of many mechanical systems can be adequately represented as a single-degree-of-freedom system as shown in Figure Q3a. The mass of the system is m kg, the linear spring stiffness is k N/m and the damping coefficient is c N/(m/s).

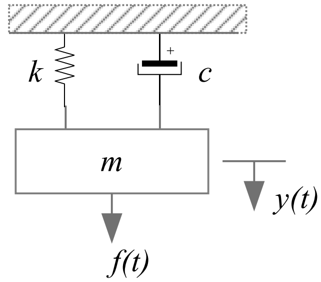

Figure Q3a

i. Draw a free body diagram of the system and derive an expression for the relationship between the output displacement, $y(t)$, and the input force, $f(t)$.

ii. Write an expression for the transfer function $G(s)$ which relates the output response $Y(s)$, the Laplace transform of $y(t)$, to the input $F(s)$, the Laplace transform of $f(t)$. Assume that the initial displacement and velocity are both equal to zero. **(6 marks)**

e. Consider a closed loop system with a unity feedback as shown in Figure Q3b.

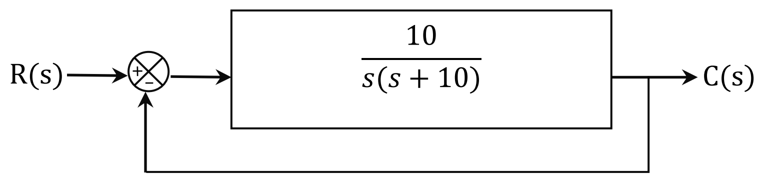

Figure Q3b

Determine the following for a unit step input:

i. Settling time,

ii. Rise time,

iii. Time to peak,

iv. Maximum overshoot **(8 marks)**

Question FOUR

a. Consider a series RLC circuit, as shown in Figure Q4a, which has $R = 100\Omega$, $L = 20H$ and $C = 50\mu F$.

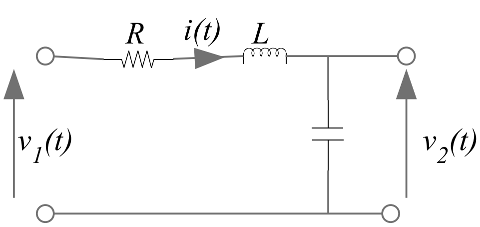

Figure Q4a.

Determine the following:

i. Write an expression for the transfer function $G(s)$ which relates the output response $V_2(s)$, the Laplace transform of $v_2(t)$, to the input $V_1(s)$, the Laplace transform of $v_1(t)$. Assume zero initial conditions.

ii. Is the system overdamped, critically damped or underdamped? **(6 marks)**

a. The quantitative analysis of a dynamic performance of control system is specified by responses to certain standard test input signals.
   i. Name any THREE standard test input signals that are commonly used during system performance analyses.
   ii. State the justification of using the test signals mentioned in (i).

(6 marks)

b. Figure Q4b shows the block diagram of a second-order system with a proportional controller with gain, K, and a unity negative feedback loop.

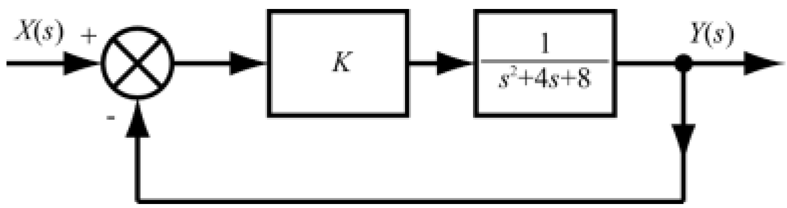

Figure Q4b.

i. Sketch the root locus diagram for this system showing how the poles vary as K increases from a value of zero.

ii. State the value of K which critically damps the closed-loop system.

iii. Comment upon the stability of the system.

(8 marks)

Question FIVE

a.
   i. Explain how the stability of a control system may be determined from a Nyquist plot.
   ii. State the disadvantages of the Nyquist plot over the Bode plot. **(5 marks)**

b. Derive expressions for radii of the constant magnitude (M) circles and constant phase (Φ) circles for a closed loop system. **(7 marks)**

c. The Nyquist plot of a unity feedback system having open loop transfer function is as shown in Figure Q5.

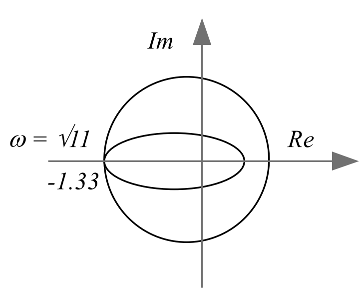

Figure Q5.

Given the open loop transfer function:

$$G(s) = \frac{K(s+5)(s+3)}{(s-2)(s-4)}$$

When K=1 the system is stable. Determine the range of K for the system to be considered stable. **(8marks)**