MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR …… SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONIC ENGINEERING)

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 514: CONTROL ENGINEERING II

DATE: **TIME:**

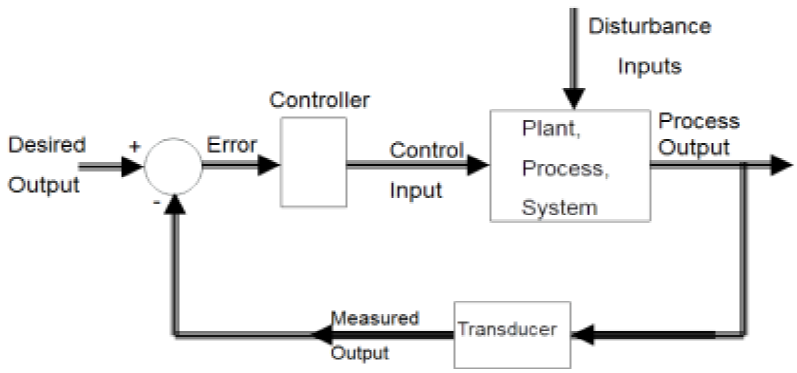
INSTRUCTIONS

- This paper consists of Five Questions.
- **Question 1** is **Compulsory.** Attempt **Any Other Two** Questions.
- Answers to any particular question must be together.

QUESTION ONE (COMPULSORY) (30MARKS)

a) Discuss the Merits and Demerits of the *Closed Loop Control System* as compared to the *Open Loop System* (5 marks)

b) A control system can be thought of as any system where additional hardware is added to regulate the behavior of a dynamic system. Control systems can either be open loop or closed loop. A closed loop system implies the use of feedback in the system. Using feedback allows us more freedom to specify the desired output behavior of the system. The most common architecture for a closed loop system is shown in Figure Q 1. Explain all the components of the Control System (6 marks)



A basic Control System Architecture

Figure Q 1

c) A cruise controller for a car that uses a simple Proportional (P) controller is to be designed. The controller is no more than a simple amplifier ($C(s) = K_p$). Consider a car of mass 1,000kg, a friction constant of 50Ns/m and an output force of the engine being 500N. Assume zero initial conditions for the output . Design the Control System by:

i) Modelling the car dynamics (3 marks)

ii) Obtaining the *Open Loop* response (3 marks)

iii) Obtain the *Closed Loop* response (8 marks)

iv) Determine the closed loop response with *disturbance* (for example wind) (5 marks)

QUESTION TWO (20 MARKS)

a) The state representation is defined by the relation

$$x\dot{(t)} = Ax(t) + Bu(t)$$

$$y(t) = Cx(t) + Du(t)$$

Show that

$$x(t) = \phi(t)X(o) + \int_0^t \phi(t-\tau)\, Bu(\tau)d\tau$$

$$y(t) = C\phi(t)X(o) + \int_0^t C\phi(t-\tau)\, Bu(\tau)d\tau + Du(t$$

All the symbols carry their usual meaning (6 marks)

b) For a Control Systems defined by the transfer functions, determine the following

$$G(s) = \frac{Y(s)}{R(s)} = \frac{1}{S^2 + 3S + 2}$$

i) Matrix differential equations for the system in OCF (2 marks)

ii) Determine the state transition matrix $\phi(t)$ (5 marks)

iii) Determine the zero-state response if a unit step is applied. Use the Convolution Integral

FOR THE INITIAL CONDITION, $X(o) = [1,0]$ (7 marks)

QUESTION THREE (20 MARKS)

a) The state representation is defined by the relation

$$x\dot{(}t) = Ax(t) + Bu(t)$$

$$y(t) = Cx(t) + Du(t)$$

$x(t) = Pv(t)$ where P is the transformation and v(t) are the transformation state vector. Derive the Similarity Transformation of the system (6 marks)

b) For the plant represented by

$$x\dot{(}t) = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 1 & 3 \\ 1 & 1 & 1 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} u(t)$$

$$y = [1\ 1\ 0\ ]\ x(t)$$

From First Principles, *Transform* the State Equations into

i) Control Canonical Form (CCF) (7 marks)

ii) Observer Canonical Form (OCF) (7 marks)

QUESTION FOUR (20 MARKS)

a) The state representation is defined by the relation

$$\dot{x(t)} = Ax(t) + Bu(t), x(o) = 0$$

$$y(t) = Cx(t) + Du(t)$$

Show that

$$G(s) = \frac{Y(s)}{X(s)} = C(sI - A)^{-1}B + D$$

All the symbols carry their usual meaning (6 marks)

b) With respect to a) above and pole-zero analogy, explain observability and controllability of the system (3 marks)

c) Determine *Transfer Function* for the control system defined by the state equations given by (4 marks**)**

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} -2 & 0 \\ -3 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u$$

$$y = \begin{bmatrix} 3 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

d) Determine *Transfer Function* for the control system defined by the state equations given by (6 marks)

$$\dot{x(t)} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ -1 & 0 & -2 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(t)$$

$$y = [1\ 0\ 0\ ]\, x(t)$$

QUESTION FIVE (20 MARKS)

a) Write the Mathematical Model of the PID Controller, in time and frequency domain. Explain all the symbols used (2 marks)

b) Derive the Transfer Function of a general closed loop PID controlled system with input R(s), output C(s), plant gain G(s) and feedback control gain H(s) (5 marks)

c) Consider the control system shown in Figure Q 5c).

i) Apply a Ziegler–Nichols tuning rule for the determination of the values of parameters K_p, T_i *and* T_d . Hence state the controller gain (9 marks)

ii) Unit Step Response of the System (4 marks)

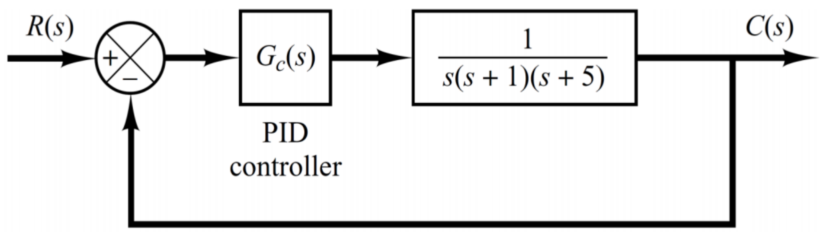


Figure Q 5c)