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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND COMMUNICATION ENGINEERING

COURSE CODE: ECE 411

COURSE TITLE: CONTROL SYSTEMS II

DATE: 22ND DECEMBER, 2022 **TIME:** 3: 00 PM – 5:00 PM

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Highlight the effects of the following controllers to a system.
   i. Proportional controller
   ii. Integral controller
   iii. Proportional and Integral (PI) controller

[6 Marks]

b) Discuss any 3 types of compensator configurations using appropriate diagrams.

[6 Marks]

c) Differentiate between the following terms as applied in control engineering
   i. State-space and State variables
   ii. Controllability and Observability
   iii. State and State vector

[6 Marks]

d) Highlight at least 2 reasons why derivative control action is not used by itself in control systems. **[2 Marks]**

e) A PID controller is inserted in series with a system having a transfer function

$$G(s) = \frac{6}{(s+5)(s+7)}$$

   i. If the system has unity feedback draw the block diagram of the system
   ii. Find the closed-loop transfer function of (i) above.
   iii. Find the gain constants of the PID controller required to locate the closed-loop poles at $s = -30, s = -2 \pm j3$.

[6 Marks]

f) In a table format outline the differences and the effects of lead and lag compensators in a control system.

[6 Marks]

QUESTION TWO (20 MARKS)

a) What is an integrator windup and highlight the three integrator anti-windup techniques.

[4 Marks]

b) Given a system:

$$G(s) = \frac{2}{s(s+4)}$$

   i. Based on root locus approach, design a phase lead controller such that for the closed-loop system, the dominant pole pair has an undamped natural frequency $\omega_n = 2$ and the damping factor $\zeta = 0.75$.
   ii. Draw the Root locus of the compensated system.

[10 Marks]

c) Compute the transfer function of the system defined by the following state space equations.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -2 & -5 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$

$$y = \begin{bmatrix} 3 & 4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

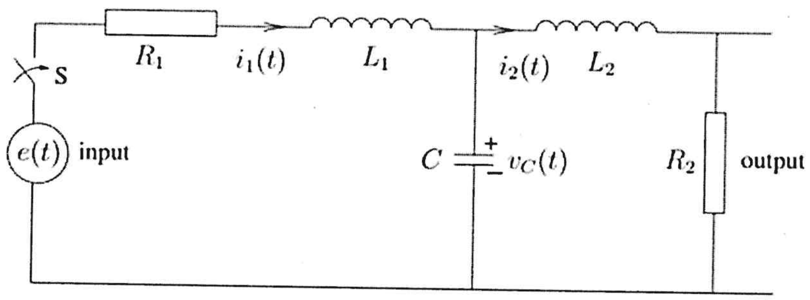
[6 Marks]

QUESTION THREE (20 MARKS)

a) State at least two conditions under which a system is not controllable.

[2 Marks]

b) Consider the circuit shown below.

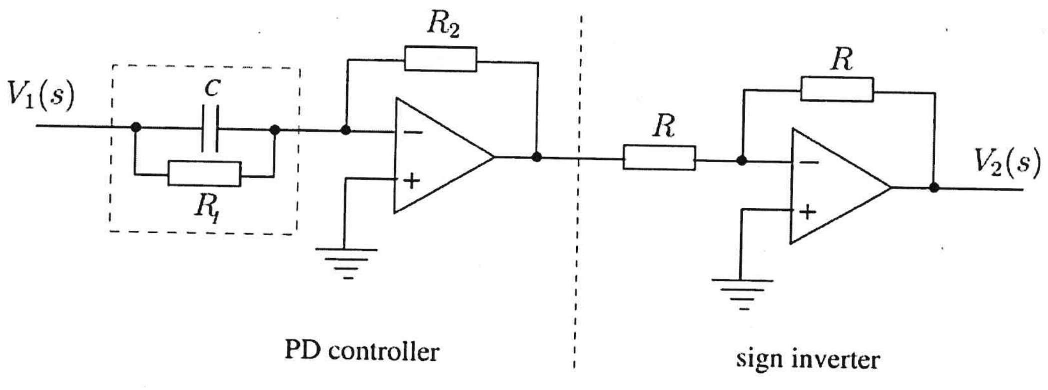


i. Taking the resister R_1 current as the state $x_1(t)$, the inductor L_2 current as the state $x_2(t)$, the capacitor voltage as state $x_2(t)$, $e(t) = u(t)$ and output voltage is $y(t)$. Obtain the state-space representation.

ii. Given that $R_1 = 8\Omega$, $L_1 = 0.25H$, $R_2 = 4\Omega$, $L_2 = 0.5H$, $C = 1F$, assuming that the switch S is closed at time $t = 0$. Use Kalman's test to determine whether the system is controllable.

[10 Marks]

c) Below is an electronic Proportional derivative controller.



i. Determine the transfer function of the circuit

ii. Find the expressions for gain constants K_P, T_D, and K_D

iii. Draw its closed loop block diagram of the system

[8 Marks]

QUESTION FOUR (20 MARKS)

a) List at most four time-domain and four frequency-domain system specifications in control systems.

[2 Marks]

b) Given a system:

$$G(s) = \frac{2}{s(s+1)}$$

Frequency ω $(rad\ sec^{-1})$	0.1	0.2	0.4	0.6	1	2	4	6	10
Gain (dB)	20	14	7	3	-3	-13	-24	-31	-40
Phase (degrees)	-96	-101	-112	-121	-135	-153	-166	-171	-174

Using the frequency response approach design a compensator for the system $G(s)$ such that the static velocity error constant $K_v = 15\ sec^{-1}$, the phase margin is at least 40°. The gain and phase of $G(j\omega)$ at certain frequencies is tabulated above.

[10 Marks]

c) Given a system described by the state equation $\dot{x} = Ax + Bu$, where $A = \begin{bmatrix} 0 & 1 \\ -13 & -4 \end{bmatrix}$ and $B = \begin{bmatrix} 0 \\ 2 \end{bmatrix}$. If $u(t) = 0$ and $x(0) = 1$, find the solution to the state equation.

[8 Marks]

QUESTION FIVE (20 MARKS)

a) Highlight at least two properties of state space models.

[4 Marks]

b) Consider a plant $G(s)$,

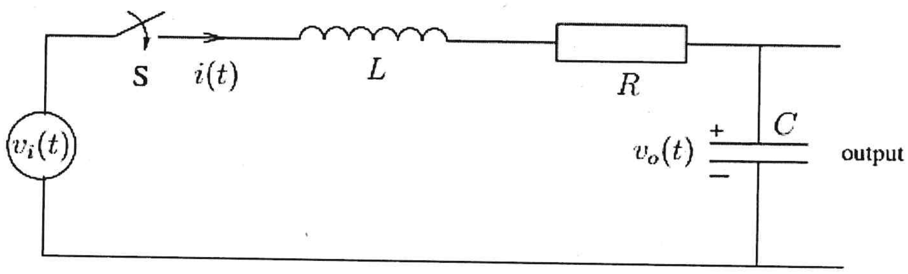
$$G(s) = \frac{1}{(s+2)(s+4)(s+6)(s+8)}$$

Given the Ziegler and Nichols coefficients for PID control in the table below, use the ultimate cycle method to determine the gains for P, PI and PID controllers

Controller	Optimum Gain		
	K_P	T	T_D
P	$0.5\ S_u$	-	-
PI	$0.45\ S_u$	$0.8333\ P_u$	-
PD	$0.6\ S_u$	-	$0.125\ P_u$
PID	$0.6\ S_u$	$0.5\ P_u$	$0.125\ P_u$

[6 Marks]

c) Consider an RLC circuit below, assume that the switch S is closed at time $t = 0$. Taking the capacitor voltage $[v_0(t)]$ as the state $x_1(t)$, $v_i(t) = u(t)$ and output voltage $v_0(t) = y(t) = x_1(t)$.



i. Determine the state-space representation of the circuit

ii. Given that $R = 0.75\Omega$, $L = 0.25H$, $C = 2F$, $u(t)$ is a unit step voltage starting at $t = 0$, and assuming zero initial conditions, determine the expressions for $x_1(t)$, $x_2(t)$ and $y(t)$ for $t \geq 0$.

[10 Marks]