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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2023/2024 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: TUESDAY 19/12/2023 **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

This Paper Consists of 4 Printed Pages. Please Turn Over.

QUESTION ONE (COMPULSORY) (30 MARKS)

a) State two advantages of the state-space representation over the transfer function representation.

[2 Marks]

b) For both time domain and frequency domain state any three system specifications in control engineering

[2 Marks]

c) Using relevant block diagrams of type 0, first order system and equations show that a PD control does not improve the steady-state performance of the system while PI improve the steady-state performance of the system

[6 Marks]

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

[6 Marks]

e) Differentiate the following terms as applied in control engineering

i. System type and system order

ii. Phase margin and Gain margin in Bode plot

iii. State variables and State vector

[6 Marks]

f) A PID controller is inserted in series with a system having a transfer function. If The system has unity feedback.

$$G(s) = \frac{10}{2s+5}$$

i. Find the gain constants of the PID controller required to locate the closed-loop poles at $s = -4 \pm j5$.

ii. Determine the undamped natural frequency ω_n of the system

iii. Determine the damping factor ζ of the system

iv. Determine the time constant τ of the system

[8 Marks]

QUESTION TWO (20 MARKS)

a) Given a system:

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

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 $\zeta = 0.75$.

[10 Marks]

b) In control system what is an integrator windup and list the methods of integrator anti-windup

[2 Marks]

c) Using the Ziegler-Nichols rules for process reaction given below

Controller	Optimum Gain		
	K_P	T_I	T_D
P	$\frac{1}{LR}$	-	-
PI	$\frac{0.9}{LR}$	$\frac{L}{0.3}$	-
PID	$\frac{1.2}{LR}$	$2L$	$0.5L$

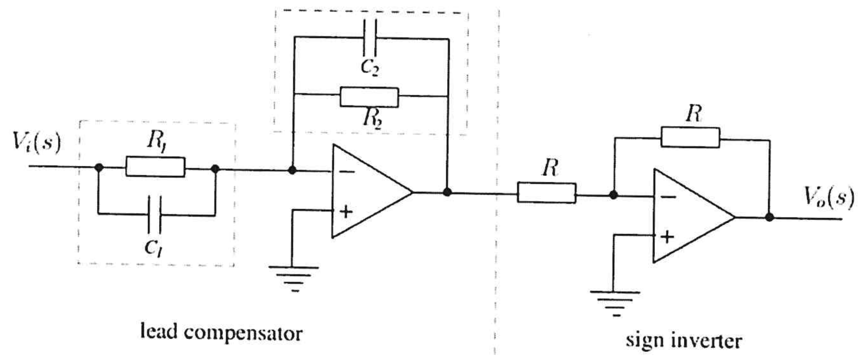
Determine the controller gains for P, PI and PID controllers for the system whose measured open-loop response of a system to a unit step is given below

t (sec)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	7.0
Amplitude	0.00	0.01	0.06	0.15	0.28	0.43	0.57	0.70	0.80	0.88	0.92	0.95	0.96	0.97

[8 Marks]

QUESTION THREE (20 MARKS)

a) Below is an electronic lead compensator



i. Determine the transfer function of the circuit

ii. Find the expressions for the compensator gain K_c, zero-pole ratio α and time constant τ

iii. What is the criteria of selecting C_1, C_2, R_1 and R_2

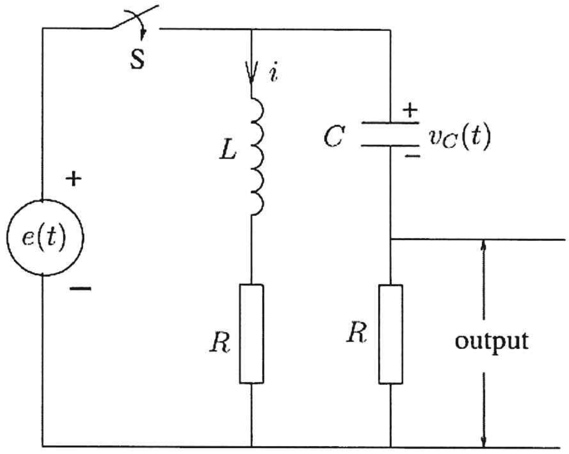
[6 Marks]

b) Represent the following system to control canonical form

$$\frac{Y(s)}{U(s)} = \frac{3s+4}{s^2+2s+5}$$

[4 Marks]

c) Consider the circuit shown below. Assuming that the switch S is closed at time $t = 0$. Taking the inductor current as the state $x_1(t)$, the capacitor voltage as state $x_2(t)$, $e(t) = u(t)$ and output voltage is $y(t)$.



i. Determine the state-space representation of the circuit

ii. Given that $R = 0.5\Omega$, $L = 0.25H$, $C = 2F$, $u(t)$ is a unit step voltage starting at $t = 0$, and assuming zero initial conditions, determine the expressions for $x(t)$, and $y(t)$ for $t \geq 0$.

[10 Marks]

QUESTION FOUR (20 MARKS)

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

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -4 & -7 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

[8 Marks]

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

[2 Marks]

c) Design a compensator for the system below

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

Using the frequency response approach design a lead 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^o. The gain and phase of $G(j\omega)$ at certain frequencies is tabulated below:

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

[10 Marks]

QUESTION FIVE (20 MARKS)

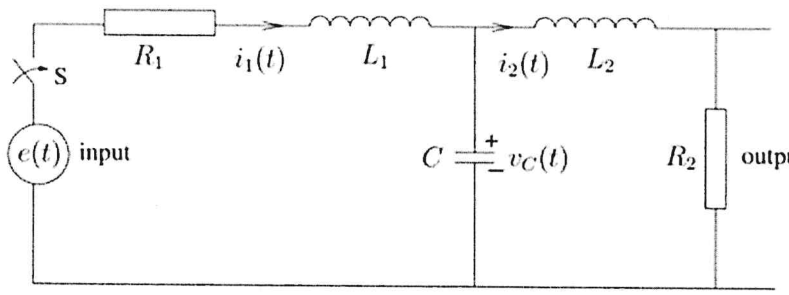
a) State the conditions for which a system is said to be unobservable

[3 Marks]

b) Considering a lead compensator show that lower corner frequency $\omega_1$and higher corner frequency ω_2 can be computed by: $\omega_1 = \frac{1}{\tau}$ and $\omega_2 = \frac{1}{\alpha\tau}$.

[7 Marks]

c) Consider the circuit shown below.



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 $y(t)$. 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 $t = 0$.

i. Use Kalman's test to determine whether the system is controllable.
ii. Use Kalman's test to determine whether the system is observable.

[10 Marks]

$f(t)$	$F(s) = \mathcal{L}[f(t)]$		Formula
$f(t) = 1$	$F(s) = \frac{1}{s}$	$s > 0$	A
$f(t) = e^{at}$	$F(s) = \frac{1}{(s-a)}$	$s > a$	B
$f(t) = t^n$	$F(s) = \frac{n!}{s^{(n+1)}}$	$s > 0$	C
$f(t) = \sin(at)$	$F(s) = \frac{a}{s^2 + a^2}$	$s > 0$	D
$f(t) = \cos(at)$	$F(s) = \frac{s}{s^2 + a^2}$	$s > 0$	E
$f(t) = \sinh(at)$	$F(s) = \frac{a}{s^2 - a^2}$	$s > \|a\|$	F
$f(t) = \cosh(at)$	$F(s) = \frac{s}{s^2 - a^2}$	$s > \|a\|$	G
$f(t) = t^n e^{at}$	$F(s) = \frac{n!}{(s-a)^{(n+1)}}$	$s > a$	H
$f(t) = e^{at}\sin(bt)$	$F(s) = \frac{b}{(s-a)^2 + b^2}$	$s > a$	I
$f(t) = e^{at}\cos(bt)$	$F(s) = \frac{(s-a)}{(s-a)^2 + b^2}$	$s > a$	J
$f(t) = e^{at}\sinh(bt)$	$F(s) = \frac{b}{(s-a)^2 - b^2}$	$s - a > \|b\|$	K
$f(t) = e^{at}\cosh(bt)$	$F(s) = \frac{(s-a)}{(s-a)^2 - b^2}$	$s - a > \|b\|$	L