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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2021/2022 FIRST SEMESTER EXAMINATIONS

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

COURSE CODE: ECE411
COURSE TITLE: CONTROL SYSTEMS II

DATE: Thursday, APRIL 21ST, 2022 **TIME: 8:00 – 10:00 AM**

INSTRUCTIONS TO CANDIDATES

- *This Paper Consists of* ***FIVE*** *Questions.*
- *Attempt Question* ***ONE*** *and* ***TWO*** *other Questions (Do not attempt more than expected).*
- *Allow* ***ONE*** *hour for Question* ***ONE*** *and another* ***ONE*** *hour for* ***TWO*** *other Questions.*
- *Question* ***ONE*** *carries* ***30 MARKS*** *and all other Questions carry* ***20 MARKS*** *each.*
- *A* ***BONUS*** *will be awarded for clean and well-organized work.*
- *Candidates are reminded to* ***STRICTLY*** *adhere to the* ***Examination Rules and Regulations.***
- ***REQUIRED:*** *Answer Booklet and Calculator.*

QUESTION ONE (COMPULSORY) (30 MARKS)

1. Discuss the effects of following controllers to a system
   i. Proportional controller
   ii. Integral controller
   iii. Proportional and Integral (PI) controller **[6 Marks]**
2. A PID controller is inserted in series with a system having a transfer function

$$G(s) = \frac{10}{(s+1)(s+2)}$$

   The system has unity feedback. Find the gain constants of the PID controller required to locate the closed-loop poles at $s = -50, s = -4 \pm j5$. **[4 Marks]**
3. Highlight 4 reasons why compensation network is needed in control systems **[4 Marks]**
4. With reference to control systems, what do you understand by the following terms.
   i. Compensator
   ii. State variables
   iii. State-space **[6 Marks]**
5. Highlight at least 2 reasons why derivative control action is not used by itself in control systems. **[2 Marks]**
6. Compute the transfer function of the system defined by the following state space equations.

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

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

   [2 Marks]
7. With a relevant closed loop system drawing and equations, show that a PD control does not improve the steady-state performance of a system. **[4 Marks]**
8. State at least 2 conditions under which a system is not controllable. **[2 Marks]**

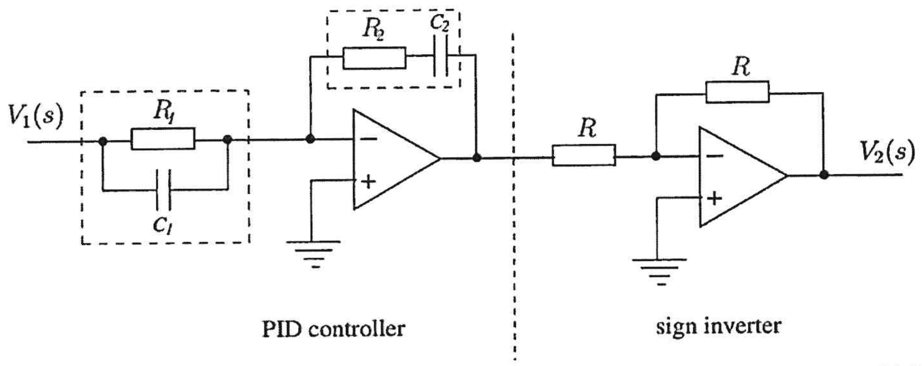
QUESTION TWO (20 MARKS)

1. Discuss any 3 types of compensator configurations using appropriate diagrams. **[6 Marks]**
2. Given a system:

$$G(s) = \frac{10}{s(s+1)}$$

   Design a phase lead controller such that for the closed-loop system, the dominant pole pair has an undamped natural frequency $\omega_n = 4$ and the damping factor $\zeta = 0.5$. Draw the Root locus of the compensated system. **[6 Marks]**

3. Compare and contrast the effects of lead and lag compensating networks in a control system. [4 Marks]
4. Below is an electronic PID controller based on an op-amp circuit. Determine its transfer function and find K_P, K_I, and K_D.



[4 Marks]

QUESTION THREE (20 MARKS)

1. Discuss at least 2 properties of state space models. **[4 Marks]**
   Explain an integrator windup and discuss three methods of integrator anti-windup with appropriate diagrams. **[6 Marks]**
2. Consider a system described by the transfer function

$$G(s) = \frac{Y(s)}{U(s)} = \frac{b_2 s^2 + b_1 s + b_0}{s^2 + a_1 s + a_0}$$

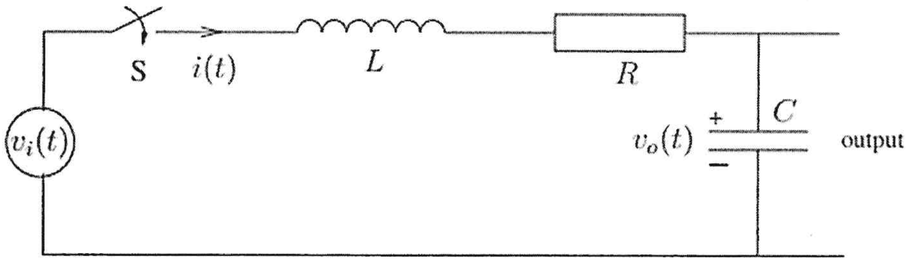
If the system is Linear-Time-Invariant such that $\dot{x} = Ax + Bu$ and $y = Cx + Du$. Proof that for a dual system, the control canonical form and observer canonical form state-space representations are related by

$$\dot{z} = A^T z + C^T v$$
$$w = B^T z + Dv$$

[10 Marks]

QUESTION FOUR (20 MARKS)

1. Highlight two techniques for tuning PID controllers. **[4 Marks]**
2. Consider the circuit given 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 $x_2(t)$, $v_i(t) = u(t)$ and output voltage $v_0(t) = y(t)$.

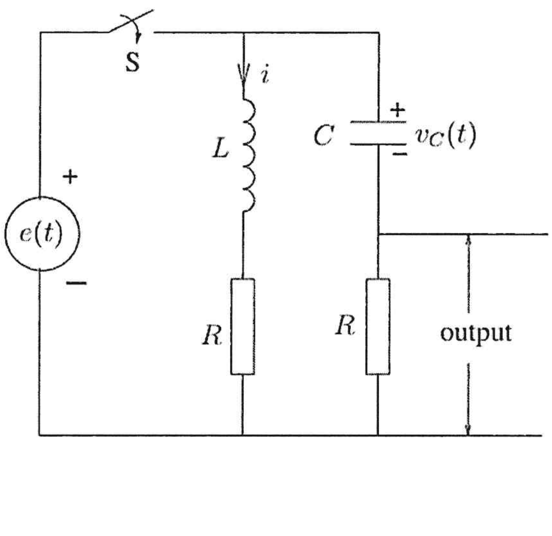


i. Obtain the state-space representation of the circuit below **[6 Marks]**

ii. Given that $R = 1.5$, $L = 0.5H$, $C = 1F$, $u(t)$ 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]**

QUESTION FIVE (20 MARKS)

1. What do you understand by the terms controllability and observability as applied to control systems? **[4 Marks]**
2. 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 $y(t)$. Use Kalman's test to determine whether the system is observable.



[10 Marks]

1. Given a system described by the state equation $\dot{x} = Ax + Bu$, where $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -30 & -31 & -10 \end{bmatrix}$ and $B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ using the control law $u = -Kx$. Determine the feedback gains if the desired location of the closed-loop poles is at $s = -4$ and $s = -6 \pm 5$

[6 Marks]