CBCS SCHEME

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17EC43

# Fourth Semester B.E. Degree Examination, Dec.2019/Jan.2020
# Control Systems

Time: 3 hrs.  Max. Marks: 100

***Note: Answer any FIVE full questions, choosing ONE full question from each module.***



## Module-1

1 a. Define closed loop control systems and list its advantages and disadvantages with examples. **(04 Marks)**

b. For the mechanical system shown in Fig.Q.1(b), write i) The mechanical network ii) the equations of motion and iii) the force-current analogous electrical network. **(08 Marks)**

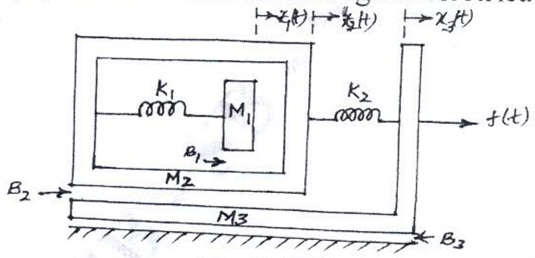


Fig.Q.1(b)

c. For the system represented by the following equations, find the transfer function X(S)/U(S) by signal flow graph technique.

$x(t) = x_1(t) + \beta_3 u(t)$

$x_1^1(t) = -a_1 x_1 + x_2 + \beta_2 u(t)$

$x_2^1(t) = -a_2 x_1 + \beta_1 u(t)$ **(08 Marks)**

**OR**

2 a. Define analogous systems. Show that two systems shown in Fig.Q.2(a) are analogous systems, by comparing their transfer functions. **(08 Marks)**

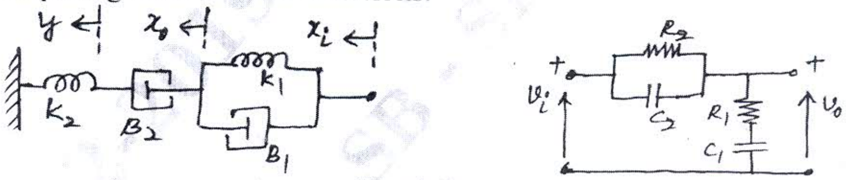


Fig.Q.2(a)

b. For the block diagram shown in Fig.Q.2(b), determine the transfer function C(S)/R(S) using block diagram reduction technique. **(08 Marks)**

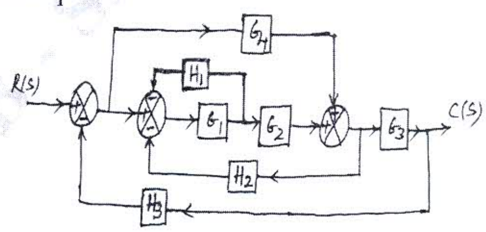


Fig.Q.2(b)

c. Define the following terms in connection with signal flow graph:
   i) Node
   ii) Forward path gain
   iii) Feedback loop
   iv) Non-touching loops. **(04 Marks)**

## Module-2

3 a. Define the following time response specifications for an underdamped second order system:
   i) Rise time, $t_r$
   ii) Peak time, $t_p$
   iii) Peak-overshoot, $M_p$
   iv) Settling time, $t_s$ **(04 Marks)**

b. A system is given by the differential equation $y''(t) + y'(t) + y(t) = x(t)$, where $y(t)$ in the output. Determine all time domain specifications for unit step input. **(08 Marks)**

c. The open loop transfer function of a unity feedback system is given by $G(s) = \dfrac{K}{S(ST+1)}$
   i) By what factor should the amplifier gain K be multiplied in order that the damping ratio is increased from 0.2 to 0.8?
   ii) By what factor should K be multiplied so that the system overshoot for unit step excitation is reduced from 60% to 20%? **(08 Marks)**

**OR**

4 a. Derive the expressions for i) Rise time, $t_r$ and ii) Peak overshoot, $M_p$ for the underdamped response of a second order system for a unit step input. **(06 Marks)**

b. For the system shown in Fig.Q.4(b), compute the values of K and $\tau$ to give an overshoot of 20% and peak time of 2 sec for an unit step excitation. **(08 Marks)**

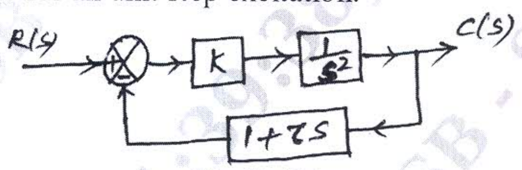


Fig.Q.4(b)

c. Find the position, velocity and acceleration error constant for a control system having open loop transfer function $G(S)H(S) = \dfrac{10}{S(S+1)}$. Also find the steady state error for the input $r(t) = 1 + t$. **(06 Marks)**

## Module-3

5 a. State and explain Routh's stability criterion for determining the stability of the system and mention its limitations. **(06 Marks)**

b. Determine the number of roots that are
   i) in the right half of s-plane
   ii) on the imaginary axis and
   iii) in the left half of s-plane

   for the system with the characteristic equation $s^6 + s^5 - 2s^4 - 3s^3 - 7s^2 - 4s - 4 = 0$. **(06 Marks)**

c. Sketch the root locus plot of a certain control system, whose characteristic equation is given by $s^3 + 10s^2 + ks + k = 0$, comment on the stability. **(08 Marks)**

**OR**

6 a. For a system with characteristic equation $s^4 + ks^3 + s^2 + s + 1 = 0$, determine the range of K for stability. **(04 Marks)**

b. Determine the values of 'k' and 'a' for the open loop transfer function of a unity feedback system is given by $G(s) = \frac{K(s+1)}{s^3 + as^2 + 3s + 1}$, so that the system oscillates at a frequency of 2rad/sec. **(06 Marks)**

c. Draw the root locus diagram for the system shown in Fig.Q.6(c), show all the steps involved in drawing the root locus. Determine:

i) The least damped complex conjugate closed loop poles and the value of 'K' corresponding to these roots

ii) Minimum damping ratio. **(10 Marks)**

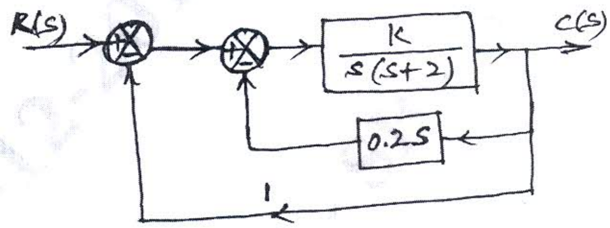


Fig.Q.6(c)

## Module-4

7 a. Define the following terms in connection with bode plots:

i) Gain cross over frequency

ii) Phase crossover frequency

iii) Gain margin

iv) Phase margin. **(04 Marks)**

b. A negative feedback control system is characterized by an open loop transfer function $G(S)H(S) = \frac{20}{S(S+1)(S+2)}$. Sketch the polar plot and hence determine $w_{gc}$, $w_{pc}$, $G_M$ and $P_M$. Comment on the stability. **(06 Marks)**

c. A unity feedback control system has $G(s) = \frac{100(1+0.1s)}{s(s+1)^2(0.01s+1)}$. Draw the Bode plots and hence determine $W_{gc}$, $W_{pc}$, GM and PM. Comment on the stability. **(10 Marks)**

**OR**

8 a. A unity feedback control system has $G(s) = \frac{200(s+2)}{s(s^2+10s+100)}$. Draw the bode plots and hence determine stability of the system. **(10 Marks)**

b. Using Nyquist stability criterion, find the range of K for closed loop stability for the negative feedback control system having the open loop transfer function $G(S)H(S) = \frac{K}{S(S^2+2S+2)}$. **(10 Marks)**

## Module-5

**9** a. State the advantages of state variable analysis. **(04 Marks)**

b. Obtain the state model for the electrical system shown in Fig.Q.9(b). Take $i_o(t)$ as output. **(06 Marks)**

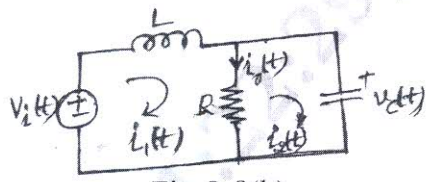


Fig.Q.9(b)

c. For a system represented by the state model

$$\begin{bmatrix} x_1'(t) \\ x_2'(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -3 & -4 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t) \text{ and } y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

Determine:

i) The state transition matrix, $\phi(t)$ and

ii) The transfer function of the system. **(10 Marks)**

**OR**

**10** a. Define state transition matrix and list its properties. **(04 Marks)**

b. Consider a state model with matrix $A = \begin{bmatrix} 0 & 1 & 0 \\ 3 & 0 & 2 \\ -12 & -7 & -6 \end{bmatrix}$. Determine the model matrix M. **(06 Marks)**

c. Obtain the time response of the following non homogeneous state equation:

$$\begin{bmatrix} x_1'(t) \\ x_2'(t) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(t)$$

where u(t) is a unit step function, when $x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ **(10 Marks)**

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# Fourth Semester B.E. Degree Examination, Dec.2019/Jan.2020
## Control Systems

Time: 3 hrs. Max. Marks: 80

*Note: Answer any FIVE full questions, choosing ONE full question from each module.*



**Module-1**

1 a. Compare open loop and closed loop control system. **(05 Marks)**

b. Find the transfer function $\frac{C(S)}{R(S)}$ for the signal flow graph shown in Fig.Q.1(b). **(05 Marks)**

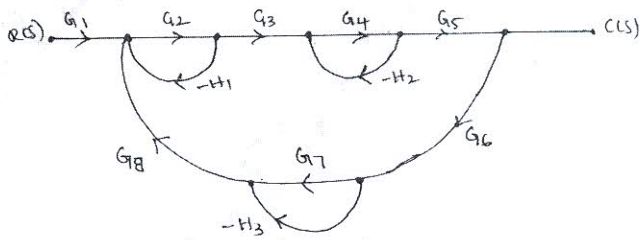



Fig.Q.1(b)

c. For the Mechanical system shown in Fig.Q.1(c):
i) Draw the mechanical network
ii) Write the differential equation
iii) Draw the force-voltage analogous electrical network. **(06 Marks)**

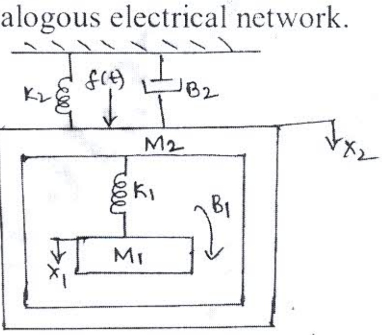



Fig.Q.1(c)

**OR**

2 a. Obtain the transfer function $\frac{\theta_2(s)}{T(s)}$ for the system shown in Fig.Q.2(a). **(05 Marks)**

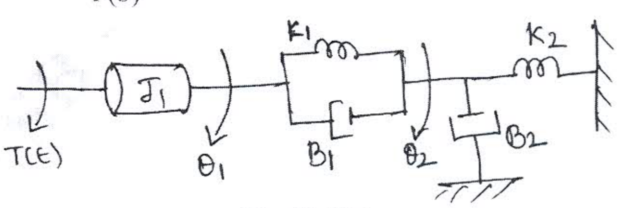



Fig.Q.2(a)

b. Obtain the transfer function $\frac{C(s)}{R(s)}$ of the system shown in Fig.Q.2(b) by using block diagram reduction technique. **(05 Marks)**

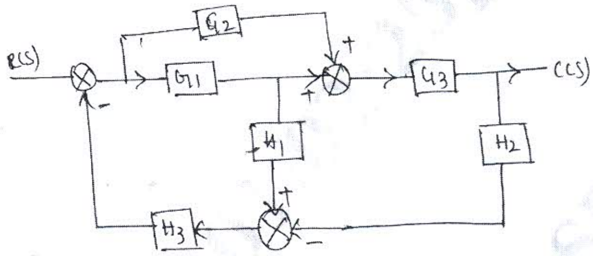



Fig.Q.2(b)

c. For the network shown in Fig.Q.2(c) construct the signal flow graph and obtain the transfer function using Mason gain formula. Given $R_1 = 100K\Omega$, $R_2 = 1M\Omega$, $C_1 = 10\mu f$, $C_2 = 1\mu f$. **(06 Marks)**

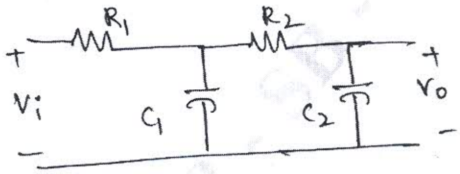



Fig.Q.2(c)

## Module-2

3 a. Derive the expression for unit step response of under damped second order system. **(08 Marks)**

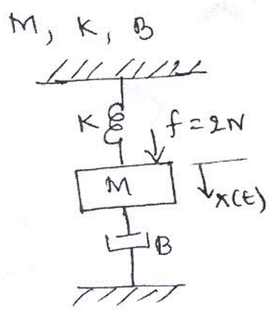
b. For a unity feedback control system with $G(S) = \frac{10(S+2)}{S^2(S+1)}$. Find the static error coefficients and steady state error when input transform is $R(S) = \frac{3}{S} + \frac{2}{S^2} + \frac{1}{3S^3}$. **(04 Marks)**

c. A units feedback control system has $G(S) = \frac{K}{S(S+10)}$ determine the gain K for $\xi = 0.5$. Also find rise time, peak time, peak overshoot and settling time. Assume system is subjected to a step of 1v. **(04 Marks)**

**OR**

4 a. Show that the steady state error $e_{ss} = \lim_{s \to o} \frac{S.R(s)}{1+G(s).H(s)}$ using simple closed loop system with negative feedback. **(04 Marks)**

b. For a spring-mass damper system shown in Fig.Q.4(b), an experiment was conducted by applying a force of 2 Newtons to the mass. The response x(t) was recorded using xy plotter and experimental result is as shown in Fig.Q.4(b) below. Find the value of M, K, B. **(07 Marks)**



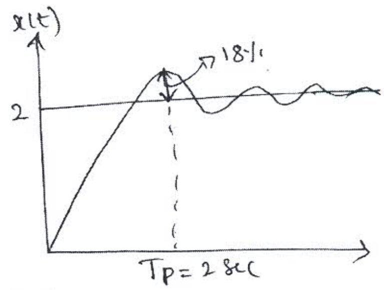




Fig.Q4(b)

c. A signal is represented by the equation $\frac{d^2\theta}{dt^2} + 10\frac{d\theta}{dt} = 150e$ where e = (r - θ) is the actuating signal, calculate the value of damping ratio, undamped and damped frequency of oscillation. Also draw the block diagram and find its closed loop transfer function. **(05 Marks)**

## Module-3

5 a. Explain the concept of Routh Hurwitz creterio. What are the necessary and sufficient conditions for the system to be stable as per Routh-Hurwitz criteria? **(05 Marks)**

b. Comment on the stability of a system using Routh's stability criteria whose characteristic equation is $s^4 + 2s^3 + 4s^2 + 6s + 8 = 0$. How many poles of systems lie in right half of s plane? **(04 Marks)**

c. Construct the root locus and show that part of the root locus is circle. Comment on stability of open loop transfer function given by $G(s) = \frac{K(s+2)}{s(s+1)}$. **(07 Marks)**

**OR**

6 a. Determine the range of K such that the characteristic equation. $S^3 + 3(k+1)S^2 + (7K+5)S + (4K+7) = 0$ has roots more negative than S = -1. **(07 Marks)**

b. A feedback control system has open loop Transfer function $G(S)H(S) = \frac{K}{S(S+4)(S^2+4S+20)}$ plot the root locus for K = 0 to ∞. Indicate all the points on it. **(09 Marks)**

## Module-4

7 a. Explain Nyquist stability criterion. **(04 Marks)**

b. Sketch the Nyquist plot for open loop transfer function $G(S)H(S) = \frac{K}{S(S+1)(S+2)}$. Find the range of K for closed loop stability. **(08 Marks)**

c. For the log magnitude diagram shown in Fig.Q.7(c) find the transfer function. **(04 Marks)**

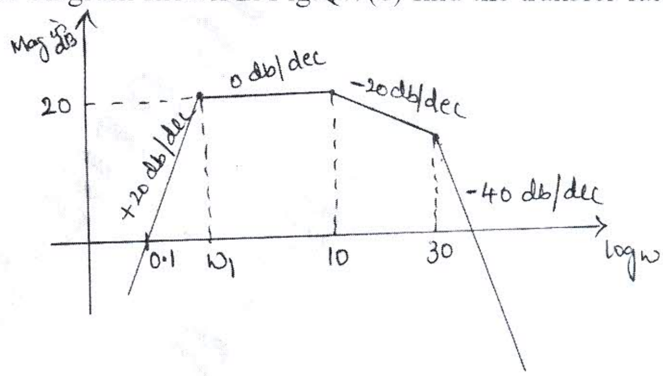



Fig.Q.7(c)

**OR**

8 a. Define Gain Margin and phase Margin. Explain how these can be determined using Bode plot. **(04 Marks)**

b. Construct the Bode magnitude and phase plot for $G(s)H(s) = \frac{100(0.1s+1)}{s(s+1)^2(0.01s+1}$. Find Gain margin and phase Margin. **(06 Marks)**

c. The polar plot of open loop transfer function of unity feedback system is shown in Fig.Q.8(c). None of the G(s) H(s) functions have poles on RHS.
   i) Complete the Nyquist path
   ii) Is the system stable
   iii) What is the system TYPE number? **(06 Marks)**

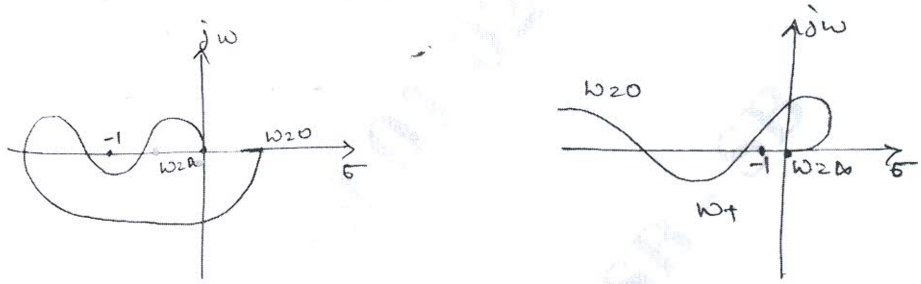



Fig.Q.8(c)

## Module-5

9 a. List the properties of state transition matrix. **(04 Marks)**

b. Obtain an appropriate state model for a system represented by an electric circuit as shown in Fig.Q.9(b). **(06 Marks)**

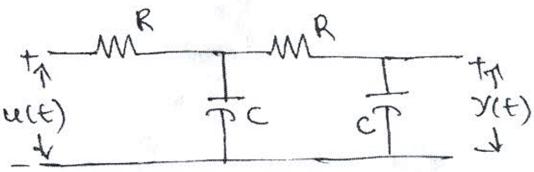



Fig.Q.9(b)

c. Find the state transition matrix for a system whose system matrix is given by

$$A = \begin{bmatrix} 0 & 1 \\ -8 & -6 \end{bmatrix}$$ **(06 Marks)**

**OR**

10 a. Draw and explain the block diagram of sample data control system. **(04 Marks)**

b. The transfer function of a control system is given by $\frac{y(s)}{u(s)} = \frac{s^2 + 3s + 4}{s^3 + 2s^2 + 3s + 2}$ obtain a state model using signal flow graph. **(08 Marks)**

c. Obtain the state model of the system shown in Fig.Q.10(c). **(04 Marks)**

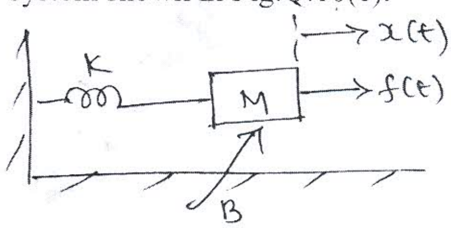



Fig.Q.10(c)

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# Fourth Semester B.E. Degree Examination, June/July 2019
## Control Systems

Time: 3 hrs. Max. Marks: 100

*Note: Answer any FIVE full questions, choosing ONE full question from each module.*



### Module-1

1 a. Define control system. Compare open loop and closed loop control system. **(06 Marks)**

b. Find the transfer function $\frac{I(s)}{Ui(s)}$ for the circuit shown in Fig.Q.1(b) and K is the gain of an ideal amplifier. **(06 Marks)**

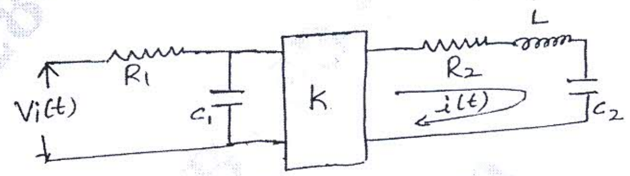


Fig.Q.1(b)

c. The system block diagram is shown in Fig.Q.1(c). Find $\frac{C(s)}{N(s)}$ if $R(s) = 0$ using block diagram reduction technique. **(08 Marks)**

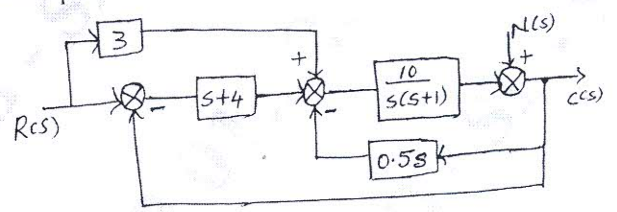


Fig.Q.1(c)

**OR**

2 a. Define signal flow graph and list the properties of signal flow graph. **(06 Marks)**

b. Find $\frac{C(s)}{R(s)}$ for the signal flow graph shown in Fig.Q.2(b) using Mason's gain formula. **(06 Marks)**

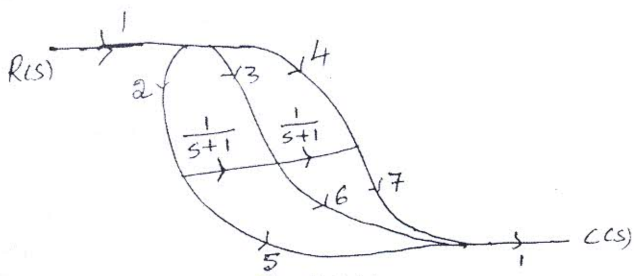


Fig.Q.2(b)

c. For the mechanical system shown in Fig.Q.2(c) i) Draw mechanical network ii) Write differential equations iii) Write the force-to-voltage analogous electric network. **(08 Marks)**

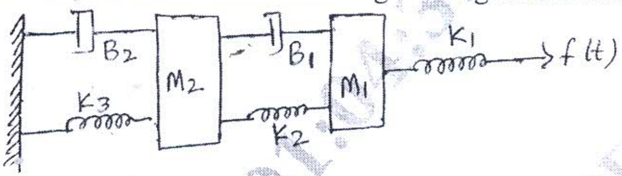


Fig.Q.2(c)

## Module-2

3 a. List the standard test input signals used for analysis and evolution of control system. Also write the Laplace transform of corresponding inputs. **(04 Marks)**

b. Find the positional error ($k_p$), velocity error ($k_v$) and acceleration error ($k_a$) coefficients for a unity feed back system with open loop transfer function $G(s)H(s) = \frac{K}{s^2(s+20)(s+30)}$. Also find 'K' to limit the steady state error to 5 units due to input $r(t) = 1 + 10t + 20t^2$. **(08 Marks)**

c. A system is given by differential equation $\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 8y(t) = 8x(t)$, where y(t) = output and x(t) = input, obtain the output response to step input. For the same calculate: Peak time, Rise time and Peak overshoot. **(08 Marks)**

**OR**

4 a. Draw the block diagram of PID controller and explain briefly. **(04 Marks)**

b. A unity feedback system has $G(s) = \frac{40(s+2)}{s(s+1)(s+4)}$.

Find: i) Type of the system ii) All error coefficients iii) Error for Ramp input with magnitude 4. **(08 Marks)**

c. A system has 30% overshoot and settling time of 5 seconds for an unit step input. Determine: i) The transfer function ii) Peak time ($T_P$) iii) Output response (Assume $C_{ss}$ as 2%). **(08 Marks)**

## Module-3

5 a. A system with characteristics equation $s^6 + 3s^5 + 4s^4 + 6s^3 + 5s^2 + 3s + 2 = 0$. Examine stability using Routh's Hurwitz criterion. **(08 Marks)**

b. Sketch the complete root locus for the system having $G(s)H(s) = \frac{K}{s(s^2+8s+17)}$. from the root locus diagram, evaluate the value of K for a system damping factor of 0.5. **(12 Marks)**

**OR**

6 a. The open loop transfer function of a unity feedback system is $G(s) = \frac{K(s+2)}{s(s+3)(s^2+5s+10)}$

i) Find the value of 'K' so that the steady state error for the input r(t) = t u(t) is less than or equal to 0.01.

ii) For the value of K found in part (i) Verify whether the closed loop system is stable or not using R.H criterion. **(08 Marks)**

b. A feedback control system has open loop transfer function $G(s)H(s) = \frac{K}{s(s+3)(s^2+3s+2)}$.

Sketch the complete root locus and comment on stability. **(12 Marks)**

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## Module-4

7 a. For a closed loop control system $G(s) = \frac{100}{s(s+8)}$ $H(s) = 1$. Determine the resonant peak and resonant frequency. **(04 Marks)**

b. Draw the polar plot whose open loop transfer function is $G(s)H(s) = \frac{1}{1+0.1s}$. **(06 Marks)**

c. Using Nyquist stability criterion, investigate the closed loop stability whose open loop transfer function is given by $G(s)H(s) = \frac{100}{(s+1)(s+2)(s+3)}$. **(10 Marks)**

**OR**

8 a. Explain lead-lag compensator. **(04 Marks)**

b. Explain Nyquist stability criterion. **(06 Marks)**

c. Sketch the Bode plot for a unity feed back system $G(s) = \frac{K}{s(s+2)(s+10)}$. Determine marginal value of 'K' for which system will be marginally stable. Using bode plot. **(10 Marks)**

## Module-5

9 a. Explain spectrum analysis of sampling process. **(06 Marks)**

b. State the properties of state transition matrix. **(06 Marks)**

c. Consider the system having state model

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -3 & 1 \\ -2 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \quad \text{and} \quad y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

with D = 0. Determine the transfer function of the system. **(08 Marks)**

**OR**

10 a. Obtain the state model of the electrical system shown in Fig.Q.10(a). **(06 Marks)**

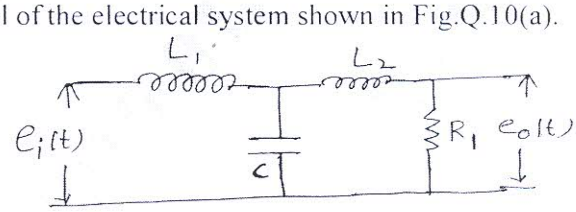


Fig.Q.10(a)

b. Obtain the state model for the system represented by the differential equation

$$\frac{d^3y(t)}{dt^3} + \frac{6d^2y(t)}{dt^2} + 11\frac{dy(t)}{dt} + 10y(t) = 3u(t)$$ **(06 Marks)**

c. Find the state transition matrix for $A = \begin{bmatrix} 0 & -1 \\ 2 & -3 \end{bmatrix}$. **(08 Marks)**

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