SRM VALLIAMMAI ENGINEERING COLLEGE
(An Autonomous Institution)
SRM Nagar, Kattankulathur – 603 203

DEPARTMENT OF
ELECTRONICS AND INSTRUMENTATION ENGINEERING

M.E CONTROL AND INSTRUMENTATION ENGINEERING

QUESTION BANK

II SEMESTER

1913203–ADVANCED CONTROL SYSTEMS

Regulation – 2019

Academic Year 2019 – 20 (EVEN)

Prepared by

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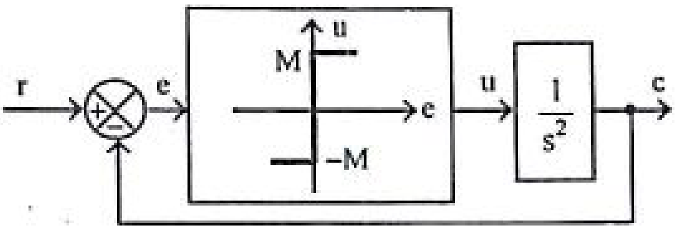
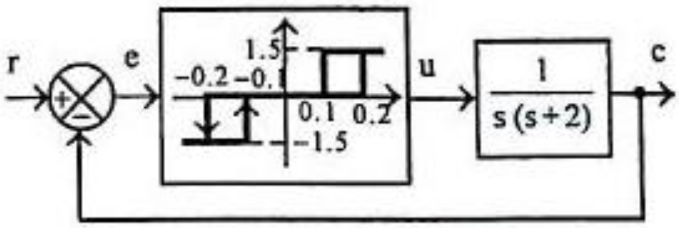
DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING

M.E Control and Instrumentation Engineering

SUBJECT: 1913203–ADVANCED CONTROL SYSTEMS
SEM / YEAR: VIII / IV

UNIT I - PHASE PLANE ANALYSIS			
SYLLABUS			
Features of linear and non-linear systems – Common physical nonlinearities – Methods of linearization – Concept of phase portraits – Singular points – Limit cycles – Construction of phase portraits – Phase plane analysis of linear and non-linear systems – Isocline method.			
PART –A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	What are linear systems and nonlinear systems? Give examples?	**BTL-2**	**Understand**
2.	How the nonlinearities are classified? Give examples?	**BTL-2**	**Understand**
3.	What is the purpose of introducing nonlinearities into the system?	**BTL-1**	**Remember**
4.	Write any two properties of non linear systems.	**BTL-6**	**Create**
5.	What is phase portrait?	**BTL-1**	**Remember**
6.	Draw the phase portrait of a stable node.	**BTL-3**	**Apply**
7.	What is singular point?	**BTL-1**	**Remember**
8.	How the singular points are classified?	**BTL-2**	**Understand**
9.	What are limit cycles?	**BTL-1**	**Remember**
10.	How limit cycles are determined from phase portrait?	**BTL-3**	**Apply**
11.	How will you determine the stable and unstable limit cycles using phase portrait?	**BTL-3**	**Apply**
12.	What is phase plane?	**BTL-1**	**Remember**
13.	What is phase trajectory?	**BTL-1**	**Remember**
14.	Write the slope equation of phase trajectories.	**BTL-6**	**Create**
15.	Write the methods for constructing phase trajectories.	**BTL-6**	**Create**
16.	How the phase trajectory is constructed in analytical method?	**BTL-4**	**Analyze**
17.	What is isocline?	**BTL-1**	**Remember**
18.	What is the difference in stability analysis of linear and nonlinear systems?	**BTL-2**	**Understand**
19.	Define the stability of a nonlinear system at origin.	**BTL-1**	**Remember**
20.	What is stable-in-the large?	**BTL-1**	**Remember**
PART – B			
1.	**(i)** The response of a system is, $y = ax + b\frac{dx}{dt}$, test whether the system is linear or nonlinear. **(7)**	**BTL-5**	**Evaluate**
	(ii) The response of a system is $y = ax^2 + e^{bx}$. Test whether the system is linear or nonlinear. **(6)**	**BTL-5**	**Evaluate**
2.	Describe the isoclines method of drawing phase plane trajectory. **(13)**	**BTL-2**	**Understand**
3.	What is phase plane, phase trajectory and phase portrait? Draw and explain how to determine the stable and unstable limit cycles using phase portrait? **(13)**	**BTL-2**	**Understand**

4.	Explain in detail about the behavior of nonlinear system and classifications of Non-linearities. **(13)**	**BTL-2**	**Understand**
5.	What are Singular points? Explain the classification of singular points. **(13)**	**BTL-2**	**Understand**
6.	Explain about the control system with linear gain and show the input based on the location of Eigen values of the system. **(13)**	**BTL-3**	**Apply**
7.	Describe the delta method of drawing Phase plane trajectory. **(13)**	**BTL-1**	**Remember**
8.	Describe analytic method of drawing Phase plane trajectory and also write procedure for phase plane trajectory. **(13)**	**BTL-1**	**Remember**
9.	Explain the construction of phase trajectory using any two methods. **(13)**	**BTL-2**	**Understand**
10.	A linear second order servo is described by the equation $\ddot{y}+2\xi\omega_n\dot{y}+\omega_n^2 y=\omega_n^2$. where ξ=0.15, ω_n=1 rad/sec, y(0)=2.0, $\dot{y}(0)=0$. Determine the singular point when (i) δ = 0 (ii) δ = 0.6. Construct the phase trajectory, using the method of isoclines. **(13)**	**BTL-3**	**Apply**
11.	Construct phase trajectory for the system described by the equation, $\frac{dx_2}{dx_1}=\frac{4x_1+3x_2}{x_1+x_2}$. Comment on the stability of the system. **(13)**	**BTL-3**	**Apply**
12.	Draw the phase trajectory of the system described by the equation $\ddot{x}+\dot{x}+x^2=0.$. Comment on the stability of the system. **(13)**	**BTL-3**	**Apply**
13.	Construct a phase trajectory by delta method for a nonlinear system represented by the differential equation, $\ddot{x}+4\lvert\dot{x}\rvert\dot{x}+4x=0$. Choose the initial conditions as x(0)=1.0, $\dot{x}(0)=0$. **(13)**	**BTL-3**	**Apply**
14.	A linear second order servo is described by the equation $\ddot{x}+2\xi\omega_n\dot{x}+\omega_n^2 x=0.$, where ξ=0.15, ω_n=1 rad/sec, x(0)=1.5, $\dot{c}(0)=0$. Determine the singular point. Construct the phase trajectory, using the method of isoclines. Choose slope as -2.0, - 0.5, 0,0.5 & 2.0. **(13)**	**BTL-6**	**Create**
	PART – C		
1.	Evaluate the type of singularity for each of the following differential equations. Also locate the singular points on the phase plane. **(15)** a) $\ddot{x}+3\dot{x}+2x=0.$ b) $\ddot{x}+5\dot{x}+6x=6.$ c) $\ddot{x}-8\dot{x}+17x=34.$	**BTL-5**	**Evaluate**
2.	Estimate the trajectories in the (t,x) plane which will extremize **(15)** $J(X)=\int_0^{t_1}\left(t\dot{x}+\dot{x}^2\right).dt$ In each of the following cases (a) t_1=1,x(o)=1,x(1)=5 (b) t_1=1,x(o)=1,x(1) is free	**BTL-5**	**Evaluate**

3.	Consider a system with an ideal relay as shown in fig. Determine the singular point. Construct phase trajectories, corresponding to initial conditions, (i) c(0) = 2, $\dot{c}(0) = 0$. ,and (ii) c(0) =2, $\dot{c}(0) = 1.5$, Take r=2 volts and M = 1.2 volts. **(15)** 	**BTL-6**	**Create**
4.	A second order servo containing a relay with dead-zone and hysteresis is shown in figure. Construct the phase trajectory of the system with initial conditions e(0)=0.65 and $\dot{e}(0) = 0$. **(15)** 	**BTL-6**	**Create**

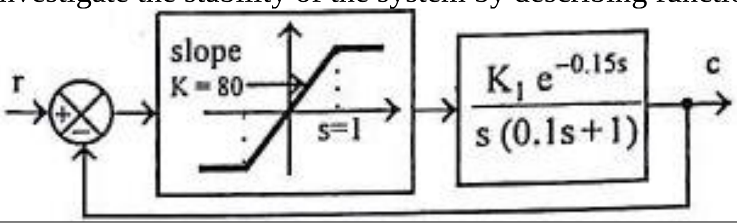
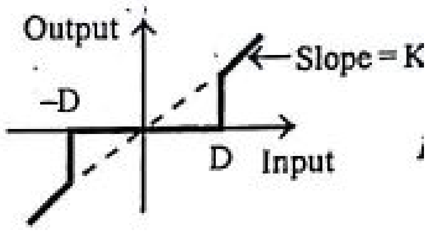
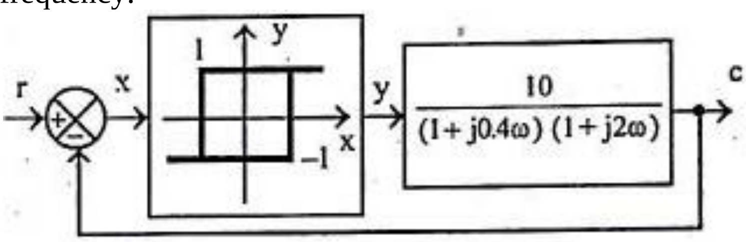
UNIT II - DESCRIBING FUNCTION ANALYSIS

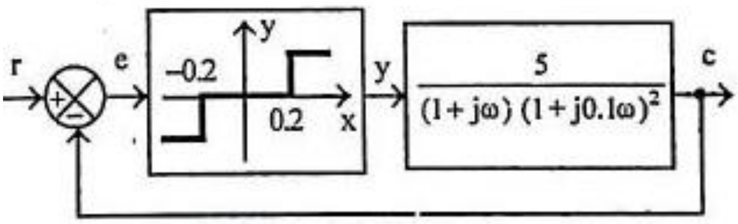
SYLLABUS

Basic concepts – Derivation of describing functions for common nonlinearities – Describing function analysis of non-linear systems – limit cycles – Stability of oscillations, Relay Feedback.

PART – A

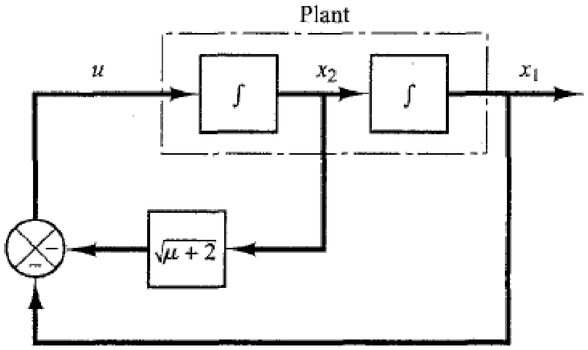
Q.No.	Questions	BT Level	Competence
1.	What is the difference between phase plane and describing function methods of analysis?	**BTL-2**	**Understand**
2.	State the limitations of analyzing nonlinear systems by describing function and phase plane methods.	**BTL-1**	**Remember**
3.	What is saturation? Give an example.	**BTL-1**	**Remember**
4.	What is dead-zone?	**BTL-1**	**Remember**
5.	What are the different types of friction?	**BTL-1**	**Remember**
6.	What is hysteresis and backlash?	**BTL-1**	**Remember**
7.	Distinguish between subharmonic and self-excited oscillations.	**BTL-4**	**Analyze**
8.	What are limit cycles?	**BTL-1**	**Remember**
9.	Write the van der pol's equation for nonlinear damping.	**BTL-6**	**Create**
10.	What is describing function?	**BTL-1**	**Remember**
11.	Explain the describing function of dead-zone and saturation nonlinearity.	**BTL-2**	**Understand**
12.	Develop the describing function of saturation nonlinearity.	**BTL-3**	**Apply**
13.	Write the describing function of dead-zone nonlinearity.	**BTL-6**	**Create**
14.	Sketch the input-output characteristic of a relay with dead-zone and hysteresis.	**BTL-3**	**Apply**
15.	Explain the describing function of ideal relay.	**BTL-2**	**Understand**
16.	Develop the describing function of relay with dead-zone.	**BTL-6**	**Create**
17.	Compose the describing function of relay with hysteresis.	**BTL-6**	**Create**
18.	Explain the describing function backlash nonlinearity.	**BTL-2**	**Understand**
19.	State the stability criterion for nonlinear systems, when the nonlinearity is	**BTL-1**	**Remember**

	replaced by the describing function K_N.		
20.	In describing function, analysis how the stability of nonlinear system is determined.	**BTL-4**	**Analyze**
	PART – B		
1.	Discuss about describing function. Give its limitations. **(13)**	**BTL-2**	**Understand**
2.	The block diagram of a system with saturation nonlinearity is shown in fig. Investigate the stability of the system by describing function method. **(13)** 	**BTL-5**	**Evaluate**
3.	Explain the describing function of saturation non-linearity. **(13)**	**BTL-2**	**Understand**
4.	Develop the describing function of dead zone of non-linearity **(13)**	**BTL-6**	**Create**
5.	Discuss the describing function of relay with dead zone. **(13)**	**BTL-2**	**Understand**
6.	Derive the describing function of on-off non-linearity. **(13)**	**BTL-6**	**Create**
7.	Explain the describing function of an on-off non-linearity with hysteresis. **(13)**	**BTL-2**	**Understand**
8.	Discuss the describing function of dead zone and saturation of non-linearity. **(13)**	**BTL-1**	**Remember**
9.	Explain about the stability analysis with describing function. **(13)**	**BTL-2**	**Understand**
10.	Find the curve with minimum arc length between the point x(0)=1 and the line t_1=4. **(13)**	**BTL-5**	**Evaluate**
11.	Find the curve with minimum arc length between the point x(0)=0 and the curve $\Theta(t)=t^2-10t+24$. **(13)**	**BTL-5**	**Evaluate**
12.	Describe limit cycles in phase portrait. **(13)**	**BTL-1**	**Remember**
13.	Explain how to study the stability of the system through describing function analysis. **(13)**	**BTL-4**	**Analyze**
14.	Determine the describing function for the nonlinear element described by, $y=x^3$, where x=input to the nonlinear element and y=output of the nonlinear element. **(13)**	**BTL-3**	**Apply**
	PART – C		
1.	Derive the describing function of the element whose input-output characteristic is shown in fig. **(15)** 	**BTL-6**	**Create**
2.	The block diagram of a system with hysteresis is shown in fig. Using describing function method, determine whether limit cycle exists in the system. If limit cycles exists them, determine their amplitude and frequency. **(15)** 	**BTL-5**	**Evaluate**

3.	A system has a nonlinear element, with describing function, $K_N=(1/X)\angle -45°$ in cascade with, $G(j\omega)=10\sqrt{2}/j\omega(1+j0.5\omega)$. Determine the limit cycle of the system. **(15)**	**BTL-5**	**Evaluate**
4.	Under the describing function analysis, prove that no limit cycle exists in the system shown in fig. Find the range of values of the dead-zone of the on-off controller for which limit cycle is predicted? **(15)** 	**BTL-5**	**Evaluate**

UNIT III - INTRODUCTION TO OPTIMAL CONTROL AND ESTIMATION			
SYLLABUS Introduction – Performance measures for optimal control problem – LQR tracking – LQR regulator – Optimal estimation – Discrete Kalman Filter.			
PART – A			
Q. No.	**Questions**	**BT Level**	**Competence**
1.	Write the concept of formulation of the optimal control problem.	**BTL-6**	**Create**
2.	Illustrate minimum time problem.	**BTL-2**	**Understand**
3.	What is minimum energy control?	**BTL-1**	**Remember**
4.	What is minimum fuel problem?	**BTL-1**	**Remember**
5.	Define state regulator problem.	**BTL-1**	**Remember**
6.	What is tracking problem?	**BTL-2**	**Understand**
7.	Explain about continuous time regulator problem.	**BTL-2**	**Understand**
8.	What is discrete time regulator problem?	**BTL-1**	**Remember**
9.	State the LQR problem.	**BTL-1**	**Remember**
10.	For an output regulator problem, develop an expression for quadratic performance index.	**BTL-6**	**Create**
11.	Give the design procedure for LQR controller.	**BTL-2**	**Understand**
12.	Draw the block diagram of Discrete Kalman Filter.	**BTL-3**	**Apply**
13.	Solution of the LQR problem of a linear time invariant system, is a time varying state feedback. Is the statement true or false? Justify	**BTL-5**	**Evaluate**
14.	State the condition for observability by Kalman-Bucy filter.	**BTL-1**	**Remember**
15.	Measure the performance index of regulator problem and solution of Matrix Riccati equation.	**BTL-5**	**Evaluate**
16.	Give the expression of Kalman gain	**BTL-2**	**Understand**
17.	Write down the expression for optimal control using Riccati equation.	**BTL-6**	**Create**
18.	Examine the PDF function for jointly Gaussian Variable	**BTL-3**	**Apply**
19.	Discuss the effect of pole-zero cancellation in transfer function	**BTL-2**	**Understand**
20.	Distinguish the terms Hamiltonian function and Hamiltonian matrix.	**BTL-4**	**Analyze**
PART-B			
1.	Derive the matrix Riccati equation and state the necessary and sufficient condition for optimal solution. **(13)**	**BTL-6**	**Create**
2.	Derive the solution of a linear quadratic regulator problem either for continuous or discrete case from the basic principle of calculaus of variations. **(13)**	**BTL-6**	**Create**

3.		Obtain the solution of Ricatti equation for the following system **(13)** $\dot{x} = ax + bu$ $\min\ J = \int_0^{\infty} \frac{1}{2}\left(qx_1^2 + u_1^2\right)dt$ Evaluate that the closed loop poles move from '-a' to '-∞'.	**BTL-5**	**Evaluate**
4.	**(i)**	Derive the necessary and sufficient condition to be satisfied along the optimal trajectory using Hamiltonian formulation starting from the results of Calculus variation approach, for a state tracking problem of a linear time invariant system. **(6)**	**BTL-6**	**Create**
	(ii)	Derive the optimal control policy for the following optimal control problem $\dot{x} = -2x + u$ $\min\ J = \frac{1}{2}\int_0^{\infty}\left((x - \sin t)^2 + u^2\right)dt$ **(7)**	**BTL-6**	**Create**
5.		Obtain the optimal control law by Ricatti equation for a continuous time system. **(13)**	**BTL-2**	**Understand**
6.		The first order system is described by the differential equation $\dot{x} = 2x(t) + u(t)$ Find the control law that minimizes the performance index $\min\ J = \frac{1}{2}\int_0^{t_1}\left(3x^2 + \frac{1}{4}u^2\right)dt$; t_f = 1 sec. **(13)**	**BTL-2**	**Understand**
7.		Determine the differential equations to be solved to obtain the solution of the following optimal control problem **(13)** $MinJ = \int_0^{10}\left(\frac{1}{2}x^1\begin{bmatrix}2 & 0\\ 0 & 0.1\end{bmatrix}x + \frac{1}{2}u^2\right)dt$ Subject to $x = \begin{bmatrix}0 & 1\\ 2 & 3\end{bmatrix}x + \begin{bmatrix}0\\ 1\end{bmatrix}u$	**BTL-3**	**Apply**
8.	**(i)**	State the solution of optimal estimation problem with the help of analogous terms of an estimation and state feedback control problems. **(8)**	**BTL-1**	**Remember**
	(ii)	Illustrate the eigen vector decomposition method of solving discrete Ricatti's equation. **(5)**	**BTL-1**	**Remember**
9.		Find the optimal control law for the system $\dot{x} = \begin{bmatrix}0 & 1\\ 1 & 1\end{bmatrix}x + \begin{bmatrix}1 & 1\\ 0 & 1\end{bmatrix}u$ with the performance index $J = \int(x_1^2 + u_1^2 + u_2^2)dt$.	**BTL-5**	**Evaluate**
10.		The regulator system contains a plant that is described by **(13)** $\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0\\ 1\end{bmatrix}u$ $y = [1\ \ 0]x$ and has a performance index $J = \int_0^{\infty}(x^T\begin{bmatrix}2 & 0\\ 0 & 1\end{bmatrix}x + u^2)dt$. Determine (i) The Riccati matrix P (ii) The state feedback matrix K.	**BTL-3**	**Apply**

11.	**(i)**	Discuss minimization of function. **(7)**	**BTL-2**	**Understand**
	(ii)	Write notes on kalman filter. **(6)**	**BTL-2**	**Understand**
12.	**(i)**	Analyze the types of optimal control problems used in control system design. Explain in detail. **(7)**	**BTL-4**	**Analyze**
	(ii)	Write the general performance index equation of the control problem and mention its requirements. **(6)**	**BTL-4**	**Analyze**
13.		Consider the system shown in Figure.  Assuming the control signal to be u(t) = -Kx(t). Determine the optimal feedback gain matrix K such that the following performance index is minimized, $J=\int_0^{\infty}(x^Tx+u^2)dt$ **(13)**	**BTL-3**	**Apply**
14.		Consider the system $\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0&1\\0&0\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix}+\begin{bmatrix}0\\1\end{bmatrix}u$. It is desired to find the optimal signal u such that the performance index $J=\int_0^{\infty}(x^TQx+u^2)dt$, $Q=\begin{bmatrix}1&0\\0&\mu\end{bmatrix}$ is minimized. Determine the optimal signal u(t). **(13)**	**BTL-3**	**Apply**
		PART – C		
1.		Analyze the optimal control law for the system $\dot{x}=\begin{bmatrix}0&1\\0&0\end{bmatrix}x+\begin{bmatrix}0\\1\end{bmatrix}u$ $y=\begin{bmatrix}1&0\\0&2\end{bmatrix}x$ such that the following performance index is minimized $J=\int(y_1^2+y_2^2+u^2)dt$ **(15)**	**BTL-4**	**Analyze**
2.		Analyze the optimal control law for the system described by $\dot{x}=\begin{bmatrix}0&1\\-2&-3\end{bmatrix}x+\begin{bmatrix}0\\1\end{bmatrix}u$ $y=\begin{bmatrix}1&0\\0&2\end{bmatrix}x$ such that the following performance index is minimized $J=\int_0^{\infty}(x^Tx+u^2)dt$ **(15)**	**BTL-4**	**Analyze**

3.	Design the multivariable optimal regulator system for the plant state equations are $\begin{bmatrix}\dot{x}_1 \\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1 \\ -4 & -2\end{bmatrix}\begin{bmatrix}x_1 \\ x_2\end{bmatrix} + \begin{bmatrix}0 \\ 4\end{bmatrix}u$ $y = [1 \quad 0]x$ If the performance index to be minimized is $J = \int_0^\infty (x^T Q x + u^2)dt$. **(15)**	**BTL-6**	**Create**
4	Design the Kalman filter for multivariable state estimation problem. **(15)**	**BTL-6**	**Create**

UNIT IV - INTRODUCTION TO SYSTEM IDENTIFICATION ADAPTIVE CONTROL			
SYLLABUS			
Introduction to system identification – The least squares estimation – The recursive least squares estimation - Correlation by frequency Analysis– Introduction to adaptive control – Gain scheduling controller – Model reference adaptive controller – Self-tuning controller.			
PART-A			
Q. No	**Questions**	**BT Level**	**Competence**
1.	What is system identification?	**BTL-1**	**Remember**
2.	Draw the black diagram of system identification.	**BTL-3**	**Apply**
3.	Give the application for industrial use of system identification.	**BTL-2**	**Understand**
4.	Define least squares algorithm.	**BTL-1**	**Remember**
5.	Define recursive lest squares algorithm.	**BTL-1**	**Remember**
6.	Write the relationship between least squares algorithm recursive lest squares algorithm.	**BTL-6**	**Create**
7.	Draw the block diagram of Recursive Least-Squares Algorithm	**BTL-3**	**Apply**
8.	When correlation analysis is required?	**BTL-2**	**Understand**
9.	What is meant by frequency analysis?	**BTL-1**	**Remember**
10.	Write the features of recursive identification method.	**BTL-6**	**Create**
11.	Define adaptive control.	**BTL-1**	**Remember**
12.	Difference between conventional control and adaptive control.	**BTL-3**	**Apply**
13.	List the classification of adaptive control with example.	**BTL-1**	**Remember**
14.	Give the advantages of adaptive control system.	**BTL-2**	**Understand**
15.	What is meant by Gain Scheduling?	**BTL-1**	**Remember**
16.	What is meant by MRAC?	**BTL-1**	**Remember**
17.	Define STC.	**BTL-1**	**Remember**
18.	Write any two practical significance of the gain Scheduling.	**BTL-6**	**Create**
19.	Difference between MRAC and STC.	**BTL-3**	**Apply**
20.	Draw the block diagram of gain scheduling.	**BTL-3**	**Apply**
PART – B			
1.	Discuss a detailed account on correlation analysis method of system identification. **(13)**	**BTL-2**	**Understand**
2.	Derive and explain the steps of the least square algorithm. **(13)**	**BTL-6**	**Create**
3.	**(i)** Describe the frequency analysis method of system parameter estimation. **(8)**	**BTL-1**	**Remember**
	(ii) Briefly describe the improved frequency analysis. **(5)**	**BTL-1**	**Remember**

<table>
<tr><td>4.</td><td>(i)</td><td>List and explain the least square algorithm for real time identification which uses a forgetting factor λ. (8)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td></td><td>(ii)</td><td>Give and discuss the properties of LSE. (5)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td>5.</td><td colspan="2">Derive and explain the steps of the Recursive least square estimation method. (13)</td><td>BTL-3</td><td>Apply</td></tr>
<tr><td>6.</td><td colspan="2">Derive the expression for the Mathematical model of a first order with pure delay system. (13)</td><td>BTL-5</td><td>Evaluate</td></tr>
<tr><td>7.</td><td colspan="2">Derive the Mathematical model of a higher order system. (13)</td><td>BTL-5</td><td>Evaluate</td></tr>
<tr><td>8.</td><td colspan="2">Briefly explain and give the application open loop and closed loop adaptive control system. (13)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td>9.</td><td colspan="2">With an example for each, explain any one parametric and non-parametric methods of system identification. (13)</td><td>BTL-1</td><td>Remember</td></tr>
<tr><td>10.</td><td colspan="2">Briefly explain passivity based adaptive control system. (13)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td>11.</td><td colspan="2">Explain the process MIT Rule based MRAS for first order system. (13)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td>12.</td><td colspan="2">Describe the Lyapunov theory based MRAS for first order system. (13)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td>13.</td><td colspan="2">Design the gain scheduling controllers. (13)</td><td>BTL-6</td><td>Create</td></tr>
<tr><td>14.</td><td colspan="2">Briefly explain direct MRAC and indirect MRAC. (13)</td><td>BTL-2</td><td>Understand</td></tr>
<tr><td colspan="5">PART-C</td></tr>
<tr><td>1.</td><td colspan="2">Discuss in detail of some practical aspects concerning for the analysis of recursive identification methods. (15)</td><td>BTL-4</td><td>Analyze</td></tr>
<tr><td>2.</td><td colspan="2">Step test have been obtained for the off-gas CO_2 concentration response obtained by changing the feed rate to a bioreactor. At k = 0, a unit step change in input u occurs, but the output change at the first sample (k=1) is not observed until the next sampling instant. The data is given in the table below. Estimate the model parameters in the second order difference equation $y(k) = a_1y(k-1)+a_2y(k-2)+b_1u(k-1)+b_2u(k-2)$. From the input-output data using the least squares approach. Plot the model response and the actual data. (15)
<table>
<tr><td>K</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Y(k)</td><td>0</td><td>0.058</td><td>0.217</td><td>0.360</td><td>0.488</td><td>0.6</td></tr>
<tr><td>K</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td></td></tr>
<tr><td>Y(k)</td><td>0.692</td><td>0.772</td><td>0.833</td><td>0.888</td><td>0.925</td><td></td></tr>
</table></td><td>BTL-5</td><td>Evaluate</td></tr>
<tr><td>3.</td><td colspan="2">Explain the Model Reference Adaptive Control (MRAC) approach and the MIT Rule in deriving a suitable control law. (15)</td><td>BTL-5</td><td>Evaluate</td></tr>
<tr><td>4.</td><td colspan="2">In sampling a continuous-time process model with h=1, the following pulse transfer function is obtained: $H(z) = (z + 1.2) / (z^2 – z + 0.25)$.The design specification states that the discrete-time closed-loop poles should correspond to the continuous-time characteristic polynomial $s^2 + 2s + 1$. Design a minimal-order discrete-time indirect self-tuning regulator. The controller should have integral action and give a closed-loop system having unit gain in stationary. Determine the Diophantine equation that solves the problem. (15)</td><td>BTL-6</td><td>Create</td></tr>
</table>

UNIT V - INTRODUCTION TO ROBUST CONTROL			
SYLLABUS			
Introduction – Norms of vectors and matrices – Norms of systems – H2 optimal controller – H2 optimal estimation – H-infinity controller – H-infinity estimation.			
PART – A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	What is robust control?	**BTL-1**	**Remember**
2.	Draw the robust performance of the system.	**BTL-3**	**Apply**
3.	What is robust stability?	**BTL-1**	**Remember**
4.	How do you find the norm of two vectors?	**BTL-3**	**Apply**
5.	How are matrices and vectors related?	**BTL-2**	**Understand**
6.	What is infinity norm of a matrix?	**BTL-1**	**Remember**
7.	What is the max norm?	**BTL-1**	**Remember**
8.	What is the inverse of a vector?	**BTL-1**	**Remember**
9.	What do you understand by the state vector and the co-state vector?	**BTL-2**	**Understand**
10.	Write down the state and co-state equations.	**BTL-6**	**Create**
11.	Draw the block diagram of an LQG controller.	**BTL-3**	**Apply**
12.	Determine the H_∞ norm of the transfer function G(s) = s+1/s+5.	**BTL-5**	**Evaluate**
13.	How do you write down the transfer function $G(s)=S(sI-A)^{-1}B+D$ in packed Matrix notation?	**BTL-4**	**Analyze**
14.	What do you understand by the H-infinity norm of a transfer function?	**BTL-2**	**Understand**
15.	What are the norms of systems?	**BTL-1**	**Remember**
16.	Sketch the block diagram of H2 optimal controller.	**BTL-3**	**Apply**
17.	What do you understand by the H2 norm of a transfer function?	**BTL-2**	**Understand**
18.	What is H2 and H_∞ control?	**BTL-2**	**Understand**
19.	Write the expression for H_∞ optimal controller to minimize the worst error from any input.	**BTL-6**	**Create**
20.	What is small gain infinity-norm control problem?	**BTL-2**	**Understand**
PART B			
1.	Explain in detail about various norms of vectors and matrices in robust control. **(13)**	**BTL-2**	**Understand**
2.	For the signal below, calculate the norms defined earlier. $u(t) = e^{-3t}$, $t\geq0$. **(13)**	**BTL-3**	**Apply**
3.	Let u(t) be the input of stable transfer function G(s) = 1/(s+1) and y(t) be the output. **(13)** 1. Calculate the 2-norm of the impulse response g(t). 2. For $u(t) = e^{-5t}$, Compute y_2.	**BTL-3**	**Apply**
4.	Calculate the 1-norm, 2-norm, and infinity-norm of vector $x=[1\ 2\ 3]^T$. **(13)**	**BTL-3**	**Apply**
5.	Given vectors $u = [0\ 1]^T$ and $v = [1\ 1]^T$, calculate the 2-norm, inner product, and the angle between them, respectively. **(13)**	**BTL-3**	**Apply**
6.	Calculate the H2 norm and H_∞ norm of stable transfer function. **(13)** $G(s)=\dfrac{s+1}{(s+2)(s+5)}$	**BTL-4**	**Analyze**
7.	Calculate the H2 norm of the following stable transfer function by using, respectively, the residue and impulse response methods **(13)** $G(s)=\dfrac{s+5}{(s+1)(s+10)}$	**BTL-5**	**Evaluate**
8.	Explain in detail stochastic H-infinity control and estimation problems both in continuous and discrete case. **(13)**	**BTL-2**	**Understand**
9.	Explain in detail stochastic H2 control and estimation problems. **(13)**	**BTL-2**	**Understand**

10.	Define an optimal control problem. Describe performance index for each case also. **(13)**	**BTL-1**	**Remember**
11.	What is Pontryagin's minimum principle ? Derive this principle from the Hamilton-Jacobi equation. **(13)**	**BTL-6**	**Create**
12.	Describe Non-Unique H-Infinity Optimal Controller. **(13)**	**BTL-2**	**Understand**
13.	Explain H2/H-Infinity Norms and Loop Shaping. **(13)**	**BTL-2**	**Understand**
14.	Discuss in detail about Sensor and contro singularity at finite frequency. **(13)**	**BTL-2**	**Understand**
	PART-C		
1.	A unity feedback control system has a nominal plant transfer function $G(s)=\frac{1}{(s+2)(s+5)}$, Design the H2 norm optimal controller. **(15)**	**BTL-5**	**Evaluate**
2.	Design the H∞ norm optimal controller of stable transfer function $G(s)=\frac{1}{(s+2)(s+5)}$. **(15)**	**BTL-4**	**Analyze**
3.	A closed loop control system has a nominal forward-path transfer function equal to $Gm(s)C(s)=\frac{K}{s(s^2+2s+4)}$. Let the bound of the multiplive model uncertainty be $\bar{l}m(s)=\frac{0.5(1+s)}{(1+0.25s)}$. What is the maximum value that K can have for robust stability? **(15)**	**BTL-6**	**Create**
4.	A plant has a transfer function $G(s)=\frac{100}{(s^2+2s+100)}$ and sentivity and complementary weighting functions $Ws(s)=\gamma\left(\frac{s+100}{s+1}\right)$ $W_T(s)=\left(\frac{s+1}{s+100}\right)$ Design the optimal value for γ and hence the state-space and transfer functions for the H∞ - optimal controller C(s). **(15)**	**-BTL-6**	**Create**