SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

SRM Nagar, Kattankulathur – 603 203

DEPARTMENT OF

ELECTRONICS AND INSTRUMENTATION ENGINEERING

QUESTION BANK

I SEMESTER

1913103–CONTROL SYSTEM DESIGN

Regulation – 2019

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Prepared by

Dr. K. AYYAR, Associate Professor/EIE

SRM VALLIAMMAI ENGINEERING COLLEGE

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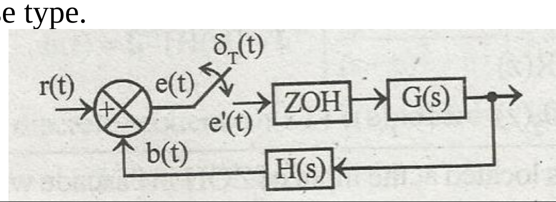
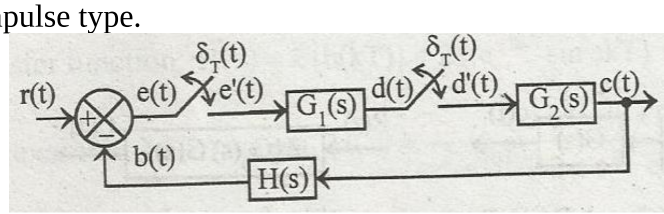
DEPARTMENT OF EIE

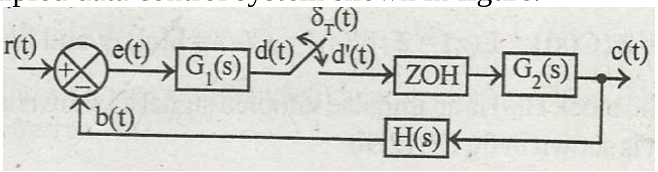
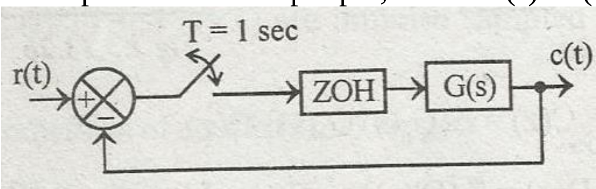
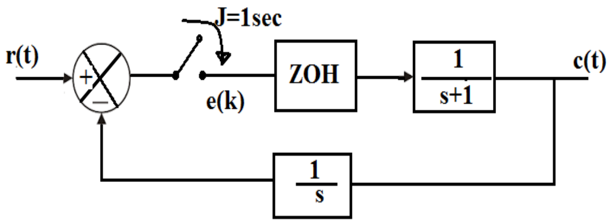
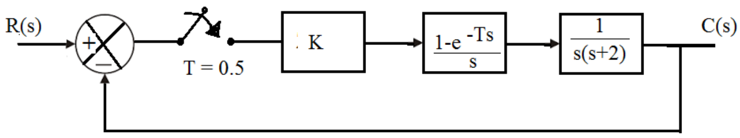
QUESTION BANK

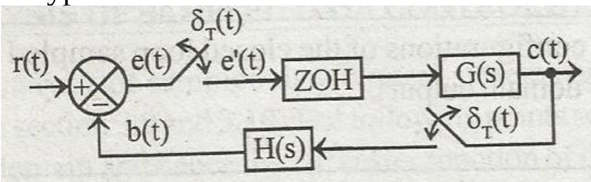
SUBJECT : 191313–CONTROL SYSTEM DESIGN

SEM / YEAR: I / I

UNIT I - CONTINUOUS AND DISCRETE SYSTEMS			
Review of continuous systems- Need for discretization-comparison between discrete and analog system. Sample and Hold devices - Effect of sampling on transfer function and state models- Analysis.			
PART –A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	When the control system is called sampled data system?	1	Remembering
2.	Distinguish between discrete time systems and continuous time systems.	4	Analyzing
3.	Compare the analog and digital controller.	4	Analyzing
4.	State (shanon's) sampling theorem.	1	Remembering
5.	What is zero-order hold?	1	Remembering
6.	Define acquisition time.	1	Remembering
7.	Examine aperture time.	3	Applying
8.	Give the problems encountered in a practical hold circuit.	2	Understanding
9.	Develop how the high frequency noise signals in the reconstructed signal are eliminated?	6	Creating
10.	Discuss discrete sequence.	2	Understanding
11.	Find z-transform of e^{-akT}.	4	Analyzing
12.	What is linear (time-invariant) discrete time system (LSD)?	1	Remembering
13.	How the output of a linear discrete-time system (LSD) is related to impulse response?	3	Applying
14.	Asses pulse transfer function.	5	Evaluating
15.	Sketch the frequency response curve of ZOH device.	3	Applying
16.	Give the steps involved in determining the pulse transfer function of G(z) from G(s).	2	Understanding
17.	How the s-plane is mapped into z-plane?	5	Evaluating
18.	List the methods of discretisation	1	Remembering
19.	Express the steps involved in converting continuous time signal into discrete time signal using impulse invariance transformation.	2	Understanding
20.	Formulate the need of Digitization.	6	Creating

<table>
<tr><th colspan="4">PART – B</th></tr>
<tr><td>1.</td><td>(i) Describe Sampled data control system in detail and explain the situations it can be used.(7)
(ii) Give the advantages of SDCS and brief about sampling process.(6)</td><td>2</td><td>Understanding</td></tr>
<tr><td>2.</td><td>Find the one sided z-transform of the discrete sequences generated by mathematically sampling the following continuous time function,
(i) cos ωt (6)
(ii) e^{-at} sin ωt (7)</td><td>4</td><td>Analyzing</td></tr>
<tr><td>3.</td><td>Determine the inverse z-transform of the following function.
$(a)\ \ F(Z) = \frac{Z^2}{Z^2 - Z + 0.5}$ (6)
$(b)\ \ F(Z) = \frac{1 + Z^{-1}}{1 + Z^{-1} + 0.5Z^{-2}}$ (7)</td><td>5</td><td>Evaluating</td></tr>
<tr><td>4.</td><td>Determine the inverse z-transform of
$F(Z) = \frac{1}{1 + \frac{3}{2}Z^{-1} + \frac{1}{2}Z^{-2}}$
When (a) ROC : IZI > 1.0 (7)
and (b) ROC : IZI < 0.5 (6)</td><td>5</td><td>Evaluating</td></tr>
<tr><td>5.</td><td>The input-output relation of a sampled data system is described by the equation
c(k+2)+3c(k+1)+4c(k)=r(k+1)-r(k).
(i)Determine the z-transform function. (5)
(ii) Also obtain the weighting sequence of the system. (8)</td><td>5</td><td>Evaluating</td></tr>
<tr><td>6.</td><td>Solve the difference equation c(k+2)+3c(k+1)+2c(k)=u(k)
Given that c(0)=1; c(1)=-3; c(k)=0 for k < 0</td><td>3</td><td>Applying</td></tr>
<tr><td>7.</td><td>Find C(z)/R(z) for the following closed loop sampled data control systems. Assume all the samplers to be of impulse type.

</td><td>4</td><td>Analyzing</td></tr>
<tr><td>8.</td><td>Find C(z)/R(z) for the following closed loop sampled data control systems. Assume all the samplers to be of impulse type.

</td><td>4</td><td>Analyzing</td></tr>
</table>

9.	Find the output C(z) in z-domain for the closed loop sampled data control system shown in figure.  	**4**	**Analyzing**
10.	For the sampled data control system shown in figure. Find the response to unit step input, where G(s)=1/(s+1).  	**4**	**Analyzing**
11.	(i) Compare various digitization schemes in terms of stability preservation, frequency matching and realizability. **(6)** (ii) Let $G(s)=\frac{2}{(s+2)}$. Discuss the effect of discretizing G(s) for control purpose using ZOH and sampling the output at every 0.02 sec and 0.05 sec. **(7)**	**3**	**Applying**
12.	(i) Consider a system described by the difference equation C(K+1)+2C(K)=r(K); C(0)=0. Obtain the system's impulse response. **(6)** (ii) For the sampled data control system, discover the output C(K) for r(t) = unit step **(7)**  	**5**	**Evaluating**
13.	Find the pulse transfer functions in the Z domain of the continuous with the following transfer functions in the Laplace domain. Assume a zero order hold element. $G_p(S)=\frac{2}{(0.1S+1)(5S+1)(S+1)}$	**4**	**Analyzing**
14.	A digital control system is shown in Figure.  When the controller gain K is unity and the sampling time is 0.5 seconds, determine (i) The open-loop pulse transfer function (ii) The closed loop pulse transfer function (iii) The difference equation for the discrete time response	**2**	**Understanding**

PART C			
1.	Find C(z)/R(z) for the following closed loop sampled data control systems. Assume all the samplers to be of impulse type. 	**4**	**Analyzing**
2.	Design the transfer function model in Z domain by solving the difference equation C(k+3) + 4.5c(k+2) + 5c(k+1) + 1.5c(k) = u(k). Given that c(0) = 0; c(1) = 0; c(2) = 2; c(k) = 0; k < 0.	**6**	**Creating**
3.	Determine the pulse transfer function in the Z-domain of the continuous with the following transfer function in the laplace domain. Assume a zero-order hold element. $$Gp(S) = \frac{5e^{-td}}{(3s+1)(s+1)}$$	**5**	**Evaluating**
4.	Develop the pulse transfer function of the following transfer function. Assume a zero-order hold element. $$Gp(S) = \frac{1}{s^2 + 0.9s + 1}$$	**6**	**Creating**

UNIT II - ROOT LOCUS DESIGN			
Design specifications-In Continuous domain - Limitations- Controller structure- Multiple degrees of freedom- PID controllers and Lag-lead compensators- Root locus design- Discretization & Direct discrete design.			
PART –A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	What are the time domain specifications needed to design a control system?	**1**	**Remembering**
2.	What is compensator? What are the different types of compensator?	**1**	**Remembering**
3.	Point out the two types of compensation schemes.	**4**	**Analyzing**
4.	Generalize the factors to be considered for choosing series or shunt/feedback compensation.	**6**	**Creating**
5.	Analyze Why compensation is necessary in feedback control system?	**4**	**Analyzing**
6.	Discuss the effect of adding a pole to open loop transfer function of a system.	**2**	**Understanding**
7.	Discuss the effect of adding a zero to open loop transfer function of a system.	**2**	**Understanding**
8.	How root loci are modified when a zero is added to open loop transfer function?	**5**	**Evaluating**
9.	How root loci are modified when a pole is added to open loop transfer function of the system?	**5**	**Evaluating**
10.	How control system design is carried using root locus?	**1**	**Remembering**

11.	What is the advantage in design using root locus.	**1**	**Remembering**
12.	Compose the transfer function of lag compensator and draw its pole-zero plot.	**6**	**Creating**
13.	Examine the characteristics of lag compensation? When lag compensation is employed?	**3**	**Applying**
14.	What is P-controller and what are its characteristics?	**1**	**Remembering**
15.	What is PD-controller and what are its effect on system performance?	**1**	**Remembering**
16.	Point out any two advantages of discrete data system.	**4**	**Analyzing**
17.	Associate the magnitude and angle criterion of root locus plot in Z-Domain	**2**	**Understanding**
18.	The lag-lead compensation will increase the order of the system by one, unless cancellation of poles and zeros occurs in the compensated system. Justify?	**5**	**Evaluating**
19.	In lead compensation the conflict between dominance condition and noise elimination can be avoided by locating the pole at how many times the value of zero location.	**3**	**Applying**
20.	Discuss discrete root locus.	**2**	**Understanding**
	PART – B		
1.	The forward path transfer function of a certain unity feedback control system is given by $G(s)=K/s(s+2)(s+8)$. Design a suitable lag compensator so that the system meets the following specifications. (i) Percentage overshoot $\leq$ 16% for unit step input, (ii) Steady state error ≤ 0.125 for unit ramp input.	**6**	**Creating**
2.	The controlled plant of a unity feedback system is $G(s)=K/s(s+10)^2$. It is specified that velocity error constant of the system be equal to 20, while the damping ratio of the dominant roots be 0.707. Design a suitable cascade compensation scheme to meet the specifications.	**6**	**Creating**
3.	Consider a unity feedback system with open loop transfer function, $G(s)=K/s(s+8)$. Deduce a lead compensator to meet the following specifications. (i) Percentage peak overshoot=9.5%. (ii) Natural frequency of oscillation, $\omega_n=12$ rad/sec. (iii) Velocity error constant, $K_v \geq 10$.	**5**	**Evaluating**
4.	Design a lead compensator for a unity feedback system with open loop transfer function, $G(s)=K/s(s+4)(s+7)$ to meet the following specifications.(i) Peak overshoot=12.63%. (ii) Natural frequency of oscillation, $\omega_n=8$ rad/sec. (iii) Velocity error constant, $K_v \geq 2.5$.	**6**	**Creating**
5.	Design a lag-lead compensator for a system with open loop transfer function $G(s)=K/s(s+0.5)$ to satisfy the following specifications. (i) Damping ratio of dominant closed-loop poles, $\zeta=0.5$. (ii) Undamping natural frequency of dominant closed loop poles, $\omega_n=5$ rad/sec. (iii) Velocity error constant, $K_v=80$ sec^{-1}.	**6**	**Creating**

6.	Consider a unity feedback system with open loop transfer function, G(s)=20/s(s+2)(s+4). Deduce a PD controller so that the closed loop has a damping ratio of 0.8 and natural frequency of oscillation as 2 rad/sec.	**5**	**Evaluating**
7.	Consider a unity feedback system with open loop transfer function, G(s)=4/s(s+1)(s+5). Deduce a PI controller so that the closed loop has a damping ratio of 0.9 and natural frequency of oscillation as 2.5 rad/sec.	**5**	**Evaluating**
8.	Consider a unity feedback system with open loop transfer function, G(s)=75/(s+1)(s+3)(s+8). Design a PID controller to satisfy the following specifications. (a) The steady state error for unit ramp input should be less than 0.08. (b) Damping ratio=0.8. (c) Natural frequency of oscillation=2.5 rad/sec.	**5**	**Evaluating**
9.	Discuss in detail the design of PID controllers using root locus techniques.	**2**	**Understanding**
10.	A feedback control system has the following open-loop transfer function $G(s)H(s)=\frac{K}{s(s+1)(s+5)}$ (i) Sketch the root locus by obtaining asymptotes, breakaway point and imaginary axis cross-over point(6) (ii) A compensating element having a transfer function G(s) = (s+2) is now included in the open loop transfer function. If the breakaway point is -0.56, Sketch the new root locus. Comment on stability of the system with and without the compensator.	**3**	**Applying**
11.	Design a lag- lead compensator of the system whose open loop transfer function $G(s)=\frac{K}{s(s+1)(s+2)}$ using root locus that meets the following specifications (i) Damping ratio $\xi = 0.45$, (ii) Undamped natural frequency $\omega_n = 3.5$ rad/sec. (iii) Velocity error constant, $K_V = 30\ sec^{-1}$.	**6**	**Creating**
12.	Consider a unity feedback control system whose forward transfer function is $G(s)=\frac{K}{s(s+2)(s+8)}$ .Design a lag-lead compensator so that $K_V = 80\ s^{-1}$ and dominant closed loop poles are located at $-2 \pm j2\sqrt{3}$.	**6**	**Creating**
13.	Consider a system whose open loop transfer function is given by $G(s)=\frac{1}{(s+1)}$. Design a suitable multiple degree of freedom controller so that, the closed loop system satisfies the following specifications: (i) Track step input and sinusoidal input (10Hz) with zero steady state error. (ii) Attenuate noise frequencies beyond 100 Hz.	**5**	**Evaluating**

14.	Consider a system whose open loop transfer function is given by $G(s)=\frac{1}{(s+3)(s+5)}$. The system is to be controlled under unity negative feedback. Design a suitable controller, so that the closed loop system meets the following specifications (i) Velocity error constant is greater than 10/s. (ii) Time constant is greater than 1s. (iii) Overshoot is less than 10%.	5	Evaluating
PART C			
1.	(i) Discuss in detail on direct discrete design. **(8)** (ii) Give the block diagram of digital controllers and explain the direct techniques**. (7)**	2	Understanding
2.	Given $Gh_0G(z)=\frac{K(z-0.9048)}{(z-1)^2}$; T = 1s. Sketch the root locus plot for $0 \leq K \leq \infty$. Using the information in the root locus plot, Evaluate the range of values of K for which the closed loop system is stable.	3	Applying
3.	Consider the digital process of a unity feedback system is described by the transfer function $Gh_0G(z)=\frac{K(z+0.717)}{(z-1)(z-0.368)}$; T = 1s. Sketch the root locus plot for $0 \leq K \leq \infty$ and from there obtain the value of K that results in marginal stability. Also find the frequency of oscillations.	5	Evaluating
4.	Design a lag-lead compensator for a system with open loop transfer function G(s)=K/s(s+0.5) to satisfy the following specifications. (i) Damping ratio of dominant closed-loop poles, $\xi=0.5$. (ii) Undamping natural frequency of dominant closed loop poles, $\omega_n=5$ rad/sec. (iii) Velocity error constant, $K_v=80\ sec^{-1}$	6	Creating

UNIT III DESIGN IN FREQUENCY RESPONSE BASED DESIGN			
Lag-lead compensators – Design using Bode plots- use of Nichole’s chart and Routh-hurwitz Criterion-Jury’s stability test- Digital design.			
PART – A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	Describe all pass system.	2	Understanding
2.	Sketch the Bode plot of lag compensator.	3	Applying
3.	What are the methods available for the stability analysis of sampled data control system?	1	Remembering

4.	Extend the compensation provided by the lag compensator is equivalent to that of a PD controller or a PI controller? Explain.	**2**	**Understanding**
5.	Define Gain Margin and Phase Margin.	**1**	**Remembering**
6.	What are the necessary conditions to be satistfied for the stability of sampled data control system?	**1**	**Remembering**
7.	Examine some frequency domain specifications	**3**	**Applying**
8.	How many rows are formed in Jury's table and what are the sufficient conditions to be checked from this table for stability?	**4**	**Analyzing**
9.	Generalize Routh stability criterion.	**6**	**Creating**
10.	When lag lead compensator is required?	**1**	**Remembering**
11.	Realize the lead compensator using R and C network components.	**2**	**Understanding**
12.	State True/False The transient response specifications can be translated into desired locations for a pair of dominant closed loop poles.	**1**	**Remembering**
13.	The damping ratio and natural frequency of oscillation of a second order system is 0.5 and 8 rad/sec respectively. Calculate the resonant peak and resonant frequency.	**3**	**Applying**
14.	Point out the main advantages of Bode plot.	**4**	**Analyzing**
15.	Construct principle of argument.	**6**	**Creating**
16.	Give the expression for maximum lag angle and the corresponding frequency.	**2**	**Understanding**
17.	Evaluate the auxillary polynomial in Routh array.	**5**	**Evaluating**
18.	Define cut-off rate.	**1**	**Remembering**
19.	Point out the advantages of Nichol's Chart.	**4**	**Analyzing**
20.	Asses Nichol's Chart.	**5**	**Evaluating**
	PART B		
1.	A unity feedback system has an open loop transfer function, $G(s)=\dfrac{K}{s(1+2s)}$. Design a suitable lag compensator so that phase margin is 40^0 and the steady state error for ramp input is less than or equal to 0.2.	**6**	**Creating**
2.	Design a phase lead compensator for the system $G(s)=\dfrac{K}{s(1+s)}$ to satisfy the following specifications. (i) The phase margin of the system $\geq 45^0$. (ii) Steady state error for a unit ramp input $\leq 1/15$. (iii) The gain crossover frequency of the system must be < 7.5 rad/sec.	**6**	**Creating**
3.	Consider the unity feedback system whose forward transfer function is $G(s)=\dfrac{K}{s(s+2)(s+8)}$. Design a lag lead compensator so that k_v=80s^{-1} and dominant closed loop poles are located at $-2 \pm j2\sqrt{3}$.	**5**	**Evaluating**

4.	The open loop transfer function of certain unity feedback control system is given by $G(s)=\frac{K}{s(s+4)(s+80)}$. It is desired to have the phase margin to be atleast 33^0 and the velocity error constant k_v=30sec^{-1}. Design a phase lag compensator.	**6**	**Creating**
5.	Design a lead compensator for a unity feedback system with open loop transfer function $G(s)=\frac{K}{s(s+1)(s+5)}$. to satisfy the following specifications. (i) Velocity error constant $k_v \geq 50$ (ii) Phase margin is $\geq 20^0$.	**6**	**Creating**
6.	The open loop transfer function of uncompensated system is $G(s)=\frac{K}{s(s+1)(s+4)}$. Design a lag lead compensator to meet the following specifications (i) Velocity error constant $k_v \geq 5$ (ii) Damping ratio=0.4.	**6**	**Creating**
7.	Discuss in detail the design of Compensators using frequency response approach to control system design.	**2**	**Understanding**
8.	Check for stability of the sampled data control systems represented by the following characteristic equation (i) $5z^2-2z+2=0$ (6) (ii) $Z^3-0.2z^2-0.25z+0.05=0$ (7)	**5**	**Evaluating**
9.	For the characteristic polynomial $F_1(z)=z^4+1.7z^3+1.04z^2-0.268z+0.024=0$, Check the necessary and sufficient condition for stability by Jury's test.	**5**	**Evaluating**
10.	How the estimation of frequency domain specifications using Nichols chart was done? Also explain the gain adjustment using Nichols chart.	**1**	**Remembering**
11.	The open loop transfer function of unity feedback system is $G(s)=\frac{Ke^{-0.2s}}{s(1+0.25s)(1+0.1s)}$. Using Nichols chart, determine the following (i) The value of K so that the gain margin of the system is 4db. (ii) The value of K so that the phase margin of the system is 40^{0}. (iii) The value of K so that resonant peak M_r of the system is 1 db. What are the corresponding values of ω_r and ω_b? (iv) The value of K so that the bandwidth ω_b of the system is 1.5 rad/sec.	**5**	**Evaluating**

12.	Use Routh stability criterion, determine the no. of roots in the left half plane, the right half plane and on imaginary axis for the given characteristic equation: (i) $s^5+4s^4+8s^3+8s^2+7s+4=0$ (ii) $s^7+5s^6+9s^5+9s^4+4s^3+20s^2+36s+36=0$	**5**	**Evaluating**
13.	(i) Using Routh criterion, determine the stability of the system represented by the characteristic equation, $s^4+8s^2+16s+5=0$. Comment on the location of the roots of characteristic equation.(6) (ii) Construct Routh array and determine the stability of the system whose characteristic equation is $s^6+2s^5+8s^4+12s^3+20s^2+16s+16=0$. Also determine the number of roots lying on right half of s-plane, left half of s-plane and on imaginary axis.	**5**	**Evaluating**
14.	Construct Routh array and determine the stability of the system represented by the characteristic equation, $s^5+s^4+2s^3+2s^2+3s+5=0$. Comment on the location of the roots of characteristic equation.	**6**	**Creating**
	PART C		
1.	The open loop transfer function of the system is $G(s)=\dfrac{K}{s^2(1+0.2s)}$. Design a suitable compensator to meet the following specifications: acceleration error constant K_A= 10; phase margin = 35^0.	**6**	**Creating**
2.	Consider the unity feedback system whose open loop transfer function is $G(s)=\dfrac{K}{s(s+3)(s+6)}$. Design a lag lead compensator to meet the following specifications (iii) Velocity error constant $k_v \geq 80$ (iv) Phase margin is $\geq 35^0$.	**5**	**Evaluating**
3.	A unity feedback ystem has open loop transfer function, $G(s)=\dfrac{20}{s(s+2)(s+5)}$. using Nichols chart, determine the closed loop frequency response and estimate M_r, ω_r and ω_b.	**5**	**Evaluating**
4.	(i) Determine the stability of SDCS described by the characteristic equation**(8)** $z^4-1.4z^3+0..4z^2+0.08z+0.002=0$ (ii) Determine the location of roots on S plane and hence the stability of the system using the characteristic polynomial $s^7+9s^6+24s^5+24s^4+24s^3+24s^2+23s+15=0$	**5**	**Evaluating**

UNIT IV -STATE VARIABLE DESIGN			
Pole Assignment Design- state and output feedback-observers - Estimated state feedback - Design examples (continuous & Discrete).			
PART – A			
Q.No	**Questions**	**BT Level**	**Competence**
1.	List the properties of state transition matrix for discrete time systems.	**1**	**Remembering**
2.	Generalize full order observer.	**6**	**Creating**
3.	Identify estimated state feedback in a sampled data systems.	**1**	**Remembering**
4.	Analyze the need for observer?	**4**	**Analyzing**
5.	Discuss pole placement by output feedback.	**2**	**Understanding**
6.	What happens if the pole placement is applied by state feedback?	**6**	**Creating**
7.	Give the modified state and output equation of a system with Luenberger observer.	**2**	**Understanding**
8.	Describe reduced order observer	**2**	**Understanding**
9.	Point out the limitation of Luenberger observer	**4**	**Analyzing**
10.	How is pole placement done by state feedback in a sampled data system?	**5**	**Evaluating**
11.	Formulate the necessary condition to be satisfied for designing state feedback.	**1**	**Remembering**
12.	Give the properties of state transition matrix of discrete time system.	**2**	**Understanding**
13.	Sketch the block diagram of the discrete time system described by the state model. $$\begin{bmatrix} x1(k+1) \\ x2(k+1) \end{bmatrix} = \begin{bmatrix} 5 & 0 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x1(k) \\ x2(k) \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(k)$$ $$y(k) = \begin{bmatrix} 6 & 7 \end{bmatrix} \begin{bmatrix} x1(k) \\ x2(k) \end{bmatrix} + 9u(K)$$	**3**	**Applying**
14.	Sketch the signal flow graph of the discrete time system described by the state model.	**3**	**Applying**
	$$\begin{bmatrix} x1(k+1) \\ x2(k+1) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -3 & 2 \end{bmatrix} \begin{bmatrix} x1(k) \\ x2(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(k);$$ $Y(k)=2x_1(k)$		
15.	Sketch the signal flow graph of the discrete time system described by the state model. $$\begin{bmatrix} x1(k+1) \\ x2(k+1) \\ x3(k+1) \\ x4(k+1) \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -9 & 7 & 0 & 2 \end{bmatrix} \begin{bmatrix} x1(k) \\ x2(k) \\ x3(k) \\ x4(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} u(k);$$ $$y(k) = \begin{bmatrix} 1 & 4 & 2 & 0 \end{bmatrix} \begin{bmatrix} x1(k) \\ x2(k) \\ x3(k) \\ x4(k) \end{bmatrix}$$	**3**	**Applying**

16.	What are the advantages of state space analysis?	**1**	**Remembering**
17.	What is state and state variable?	**1**	**Remembering**
18.	Construct the block diagram of a state model using the basic elements.	**5**	**Evaluating**
19.	Point out the disadvantages in choosing phase variable for state-space modelling?	**4**	**Analyzing**
20.	What is resolvant matrix?	**1**	**Remembering**
	PART – B		
1.	Consider a linear system described by the transfer function. $\frac{Y(s)}{U(s)}=\frac{5}{s(s+2)(s+3)}$ Design a feedback controller with a state feedback so that the closed loop poles are placed at -1, -2±2j.	**5**	**Evaluating**
2.	A single input system is described by the following state equation. $\begin{bmatrix}x1\\x2\end{bmatrix}=\begin{bmatrix}1 & -1\\0 & 1\end{bmatrix}\begin{bmatrix}x1\\x2\end{bmatrix}+\begin{bmatrix}1\\1\end{bmatrix}u$ Design a state feedback controller which will give closed-loop poles at 0.4, 0.6.	**6**	**Creating**
3.	A single input system is described by the following state equation. $\begin{bmatrix}x1\\x2\\x3\end{bmatrix}=\begin{bmatrix}0 & 0 & 1\\-3 & -2 & 0\\0 & -3 & 2\end{bmatrix}\begin{bmatrix}x1\\x2\\x3\end{bmatrix}+\begin{bmatrix}0\\6\\0\end{bmatrix}u$ Design a state feedback controller which will give closed-loop poles at -7, -1±j1.	**6**	**Creating**
4.	A single input system is described by the following state equation. $\begin{bmatrix}x1(k+1)\\x2(k+1)\\x3(k+1)\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\0 & 1 & 1\\0 & -2 & -3\end{bmatrix}\begin{bmatrix}x1(k)\\x2(k)\\x3(k)\end{bmatrix}+\begin{bmatrix}0\\0\\1\end{bmatrix}u(k)$ Design a state feedback controller which will give closed-loop poles at -3, -5 and 2.	**6**	**Creating**
5.	Consider the system described by the state model X=AX $where\ A=\begin{bmatrix}-1 & 1\\1 & -2\end{bmatrix};C=\begin{bmatrix}1 & 0\end{bmatrix}$ Y=CX Design a full-order observer. The desired eigenvalues for the observer matrix are μ_1= -5 ; μ_2= -5.	**5**	**Evaluating**

6.	A discrete time system has the transfer function $$\frac{Y(z)}{U(z)} = \frac{6z^3 - 15z^2 + 7z + 5}{(z-2)^2(z+1)}$$ Determine the state model of the system in (a) phase variable form (b) Jordon canonical form.	**5**	**Evaluating**
7.	A discrete time system is described by the difference equation. y(k+2) + 5y(k+1) + 4y(k) = 5u(k) y(0) = y(1) = 0; T = 1 sec (a) Determine a state model in canonical form. (b) Find the state transition matrix. (c) For input u(k) = 1; k ≥ 1, find the output y(k)	**5**	**Evaluating**
8.	Find the state transition matrix for the following case. $$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -0.5 & 1.5 \end{bmatrix}$$	**5**	**Evaluating**
9.	Find the state transition matrix e^{At} using Cayley-Hamilton theorem, for the system matrix $$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$$	**5**	**Evaluating**
10.	Compute the state transition matrix A^k using Cayley-Hamilton theorem. $$A = \begin{bmatrix} 3 & 0 \\ 0 & -3 \end{bmatrix}$$	**3**	**Applying**
11.	Determine $e^{\lambda t}$ for the following system using Cayley-Hamilton theorem. $$A = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -2 & 1 \\ 0 & 0 & -2 \end{bmatrix}$$	**5**	**Evaluating**
12.	Consider the state model given by $$x_{k+1} = \begin{bmatrix} -1 & 1 \\ 0 & -5 \end{bmatrix} x_k + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u_k$$ $$y_k = \begin{bmatrix} 1 & 0 \end{bmatrix} x_k$$ (i) Show that all the states are observable. (4) (ii) Design a full order observer so that observation error dynamics dies down in 5 sampling intervals.(5) (iii) Show that a reduced order observer can also be designed so that observation error dies down in 5 sampling intervals. (4)	**5**	**Evaluating**
13.	Consider a digital control system x(k+1)T = A x(kT) + B u(kT) where $A = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix}$ $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$. The state feedback control is described by u(kT) = -K x(kT) where K = [k_1 k_2].Find the values of k_1 and k_2 so that the roots of the characteristic equation of the closed loop	**5**	**Evaluating**

14.	Consider the system $\dot{x} = Ax + bu$ $y = cx + du$ Where $A = \begin{bmatrix} -2 & -1 \\ 1 & 0 \end{bmatrix}$; $b = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$; $c = \begin{bmatrix} 0 & 1 \end{bmatrix}$; $d = \begin{bmatrix} 2 & 0 \end{bmatrix}$ Design a full-order state observer so that the estimation error will decay in less than 4 seconds.	**6**	**Creating**
	PART C		
1.	A single input system is described by the following state equation. $\begin{bmatrix} x1(k+1) \\ x2(k+1) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -4 & -5 \end{bmatrix} \begin{bmatrix} x1(k) \\ x2(k) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(k)$ Design a state feedback controller which will give closed-loop poles at 1.5, 0.3.	**6**	**Creating**
2.	Determine the STM for the system having system matrix of 3x3 Jordon block with eigenvalues λ_1.	**5**	**Evaluating**
3.	The dynamic equations of a digital process are given as x(k+1) = A x(k) + B u(k) ; c(k) = D x(k) Where $A = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$ $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ $D = \begin{bmatrix} 1 & 1 \end{bmatrix}$ the state feedback control is u(k) = -G x(k) where G = [g1 g2] . Design a full order observer so that x(k) is observed from c(k).	**6**	**Creating**
4.	In case study a control system has an open-loop transfer function $G(s)H(s) = \frac{1}{s(s+2)(s+5)}$. The controller was a PD controller of the form $G(s) = K_1(s+a)$ with K_1 = 15 and a = 1, the system closed loop poles were s = -3.132±j3.253 and s = -0.736 with the resulting characteristic equation $s^3 + 7s^2 + 25s + 15 = 0$. Demonstrate that the same result can be achieved using state feedback methods.	**3**	**Applying**

UNIT V - LQR AND LQG DESIGN

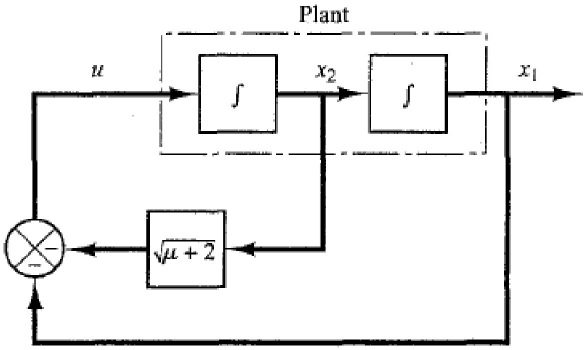
Formulation of LQR problem- Pontryagin's minimum principle and Hamiltonian solutions-Ricatti's equation – Optimal estimation- Kalman filter –solution to continuous and discrete systems - Design examples.

PART – A

Q. No	Questions	BT Level	Competence
1.	State the LQR problem	**1**	**Remembering**
2.	For an output regulator problem, develop an expression for quadratic performance index	**6**	**Creating**
3.	State the duality between the controller and the observer design problems.	**1**	**Remembering**

4.	Is the Ricatti's equation linear and time-invariant? Explain	**4**	**Analyzing**
5.	Point out the control and state variable inequality constraints.	**4**	**Analyzing**
6.	Examine the general matrix Ricatti equation	**3**	**Applying**
7.	Examine the PDF function for jointly Gaussian Variable	**3**	**Applying**
8.	Discuss the effect of pole-zero cancellation in transfer function	**2**	**Understanding**
9.	Distinguish the terms Hamiltonian function and Hamiltonian matrix.	**4**	**Analyzing**
10.	Describe Kalman filter?	**2**	**Understanding**
11.	What is the necessary and sufficient condition for optimal control "u" to minimize the Hamiltonian function?	**1**	**Remembering**
12.	Give the design procedure for LQR controller.	**2**	**Understanding**
13.	Draw the block diagram of Discrete Kalman Filter.	**3**	**Applying**
14.	Solution of the LQR problem of a linear time invariant system, is a time varying state feedback. Is the statement true or false? Justify	**5**	**Evaluating**
15.	State Pontryagin's minimum principle	**1**	**Remembering**
16.	State the Hamiltonian-Jacobi equation.	**1**	**Remembering**
17.	State the condition for observability by Kalman-Bucy filter.	**1**	**Remembering**
18.	Measure the performance index of regulator problem and solution of Matrix Riccati equation.	**5**	**Evaluating**
19.	Give the expression of Kalman gain	**2**	**Understanding**
20.	Write down the expression for optimal control using Riccati equation.	**6**	**Creating**
	PART – B		
1.	Derive the matrix Riccati equation and state the necessary and sufficient condition for optimal solution.	**6**	**Creating**
2.	Derive the solution of a linear quadratic regulator problem either for continuous or discrete case from the basic principle of calculaus of variations.	**6**	**Creating**
3.	Obtain the solution of Ricatti equation for the following system $\dot{x} = ax + bu$ $\min\ J = \int_0^\infty \frac{1}{2}\left(qx_1^2 + u_1^2\right)dt$ Show that the closed loop poles move from '-a' to '-∞'.	**2**	**Understanding**

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)** (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)**	**6**	**Creating**
5.	Obtain the optimal control law by Ricatti equation for a continuous time system.	**2**	**Understanding**
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.	**2**	**Understanding**
7.	Determine the differential equations to be solved to obtain the solution of the following optimal control problem $MinJ = \int_0^{10}\left(\frac{1}{2}x^1\begin{bmatrix}2 & 0\\0 & 0.1\end{bmatrix}x + \frac{1}{2}u^2\right)dt$ Subject to $x = \begin{bmatrix}0 & 1\\2 & 3\end{bmatrix}x + \begin{bmatrix}0\\1\end{bmatrix}u$	**3**	**Applying**
8.	(i) State the solution of optimal estimation problem with the help of analogous terms of an estimation and state feedback control problems. **(8)** (ii) Illustrate the eigen vector decomposition method of solving discrete Ricatti's equation. **(5)**	**1**	**Remembering**
9.	(i) Discuss minimization of function (ii) Write notes on kalman filter.	**2**	**Understanding**
10.	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 $J = \int (x_1^2 + u_1^2 + u_2^2)dt$.	**5**	**Evaluating**
11.	The regulator system contains a plant that is described by $\begin{bmatrix}\dot{x}_1\\\dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\-1 & -2\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix} + \begin{bmatrix}0\\1\end{bmatrix}u$ $y = [1 \quad 0]x$	**3**	**Applying**

	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.		
12.	(i) Analyze the types of optimal control problems used in control system design. Explain in detail. (ii) Write the general performance index equation of the control problem and mention its requirements.	**4**	**Analyzing**
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, $J = \int_0^\infty (x^T x + u^2) dt$	**3**	**Applying**
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 $J = \int_0^\infty (x^T Q x + u^2) dt$, $Q = \begin{bmatrix} 1 & 0 \\ 0 & \mu \end{bmatrix}$ is minimized. Determine the optimal signal u(t).	**3**	**Applying**

PART C

1.	Analyze the optimal control law for the system **(BTL-4)** $\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$ $y = \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix} x$ such that the following performance index is minimized $J = \int (y_1^2 + y_2^2 + u^2) dt$	**4**	**Analyzing**

2.	Analyze the optimal control law for the system described by **(BTL-4)** $\dot{x} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$ $y = \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix} x$ such that the following performance index is minimized $J = \int_0^\infty (x^T x + u^2) dt$	**4**	**Analyzing**
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 $J = \int_0^\infty (x^T Q x + u^2) dt$ **.**	**6**	**Creating**
4.	Design the Kalman filter for multivariable state estimation problem.	**6**	**Creating**