PRATHYUSHA ENGINEERING COLLEGE

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

EC8391-CONTROL SYSTEM ENGINEERING

Unit-I

PART-A

1. Compare the open loop system with closed loop system.
2. What are the characteristics of negative feedback.
3. Write Mason's gain formula of Signal flow graph.
4. Define transfer function.
5. What are the properties of Signal flow graphs?
6. Define transfer function.
7. Write the force balance equation for ideal mass element.
8. What is meant by block diagram. What are the basic components of block diagram.
9. What are the advantages of Closed loop System?
10. Name any two dynamic models to represent control system.
11. List the basic elements used for modelling a mechanical rotational system and mechanical translational system .
12. What is feedback? What type of feedback is employed in Control system?
13. Write T-V and T-C Analogy for the elements of mechanical rotational system?
14. Write any two rules to be followed in block diagram reduction techniques
15. Name the two types of electrical analogous for mechanical system.
16. Write force balance equation of ideal spring, ideal mass.
17. What is a Control System?
18. What are the two major types of control system.
19. Define non-touching loop.
20. Write the rule for eliminating negative feedback loop.
21. Write the force balance equation for ideal dashpot.

22. What is the basis for framing the rules of block diagram reduction technique.

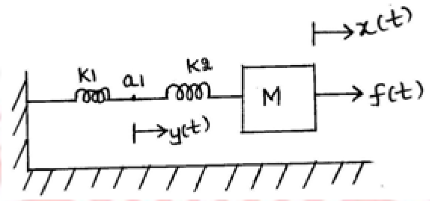
23. Write the rule for moving summing point ahead of a block.

24. Write the rule for moving branch point before a block.

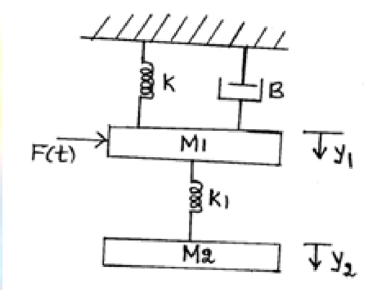
25. Define linear time invariantsystem.

PART-B

1. Determine the transfer function, X(s)/F(s) and draw the force voltage and force current electrical analogous circuits for the mechanical system shown in fig.



2. Determine the transfer function Y2(s)/F(s)) and draw the force voltage and force current electrical analogous circuits for the mechanical system shown in figure below:



3. Determine the overall transfer function and draw the torque voltage and torque current electrical analogous circuits for the following mechanical system shown in fig(1) &(2):

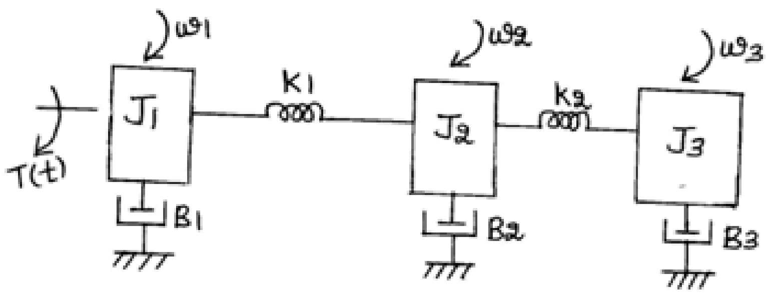


Fig.(1)

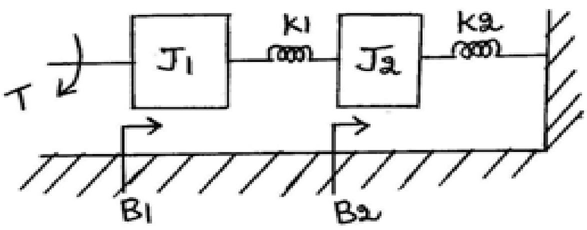
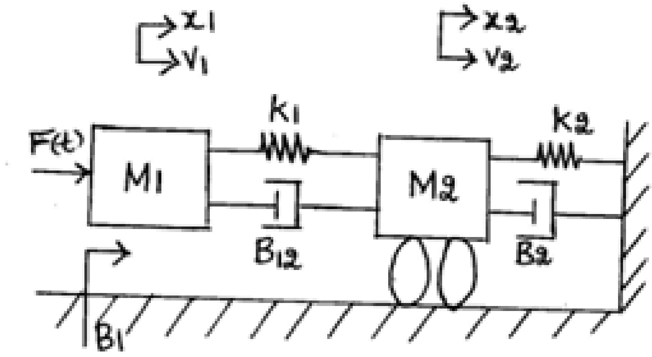
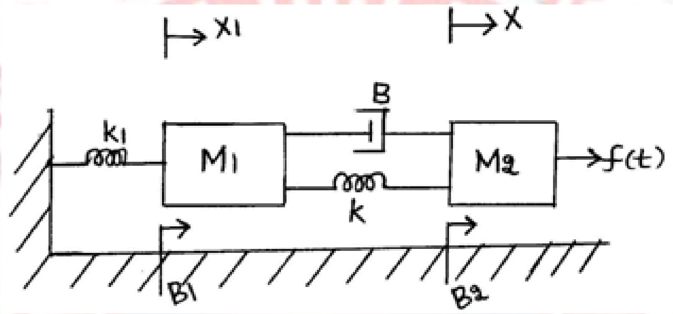


Fig.(2)

4. Determine the overall transfer function and draw the force voltage and force current electrical analogous circuits for the following mechanical system shown in fig(3) &(4):

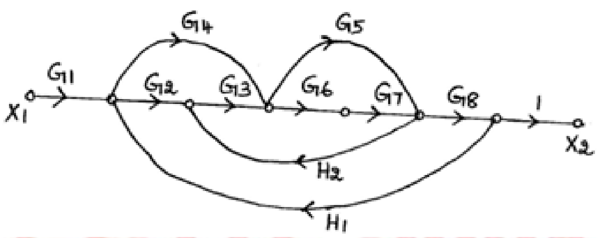


Fig(3)



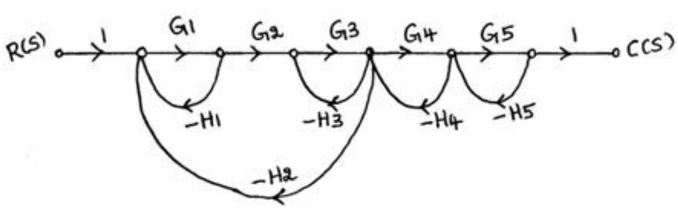
Fig(4)

5. Find the transfer function for the signal flow graph shown in fig(5),

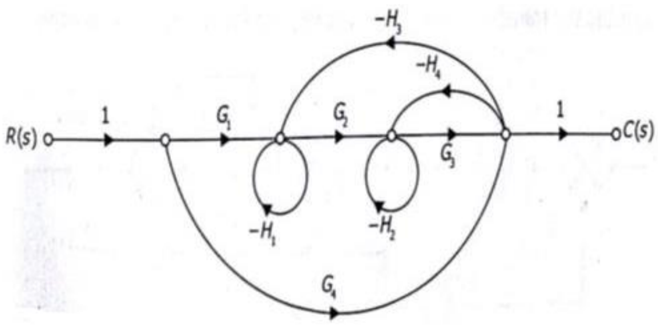


Fig(5)

6. Find the transfer function for the signal flow graph shown in fig(6),(7):

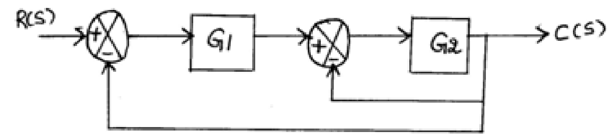


Fig(6)

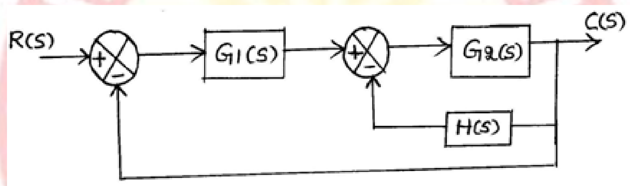


Fig(7)

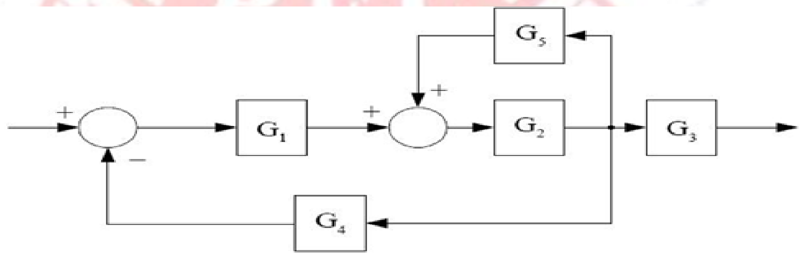
7. Determine C(s)/R(s) using block reduction method and Mason's gain formula for fig(8),(9),(10).



Fig(8)

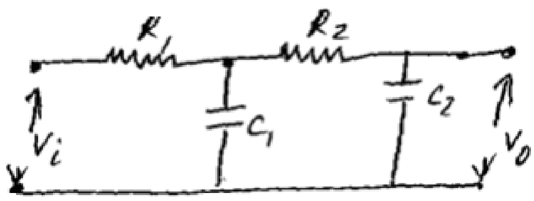


Fig(9)

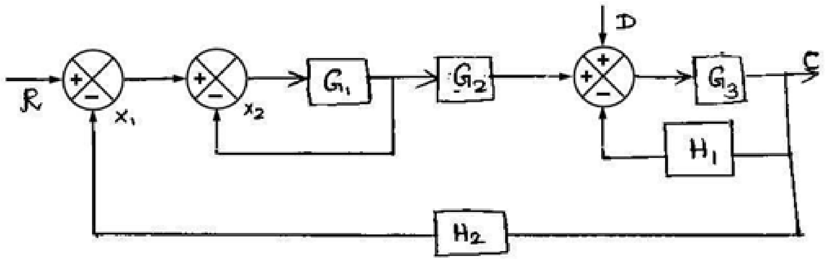


Fig(10)

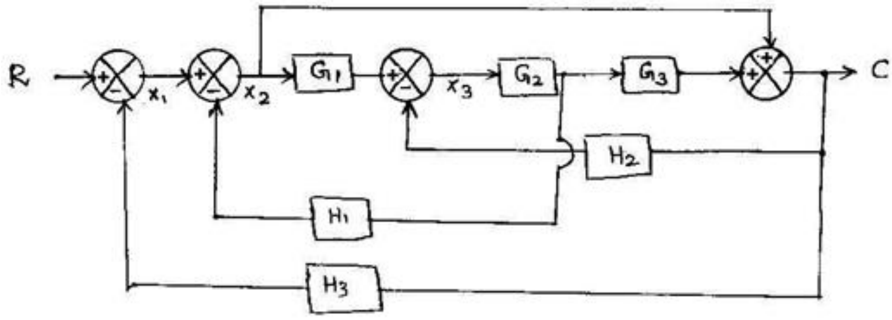
8. Determine the Transfer function of the electrical network shown in the fig.



9. For the block diagram shown below, Find the output C/R for Fig(11), (12),

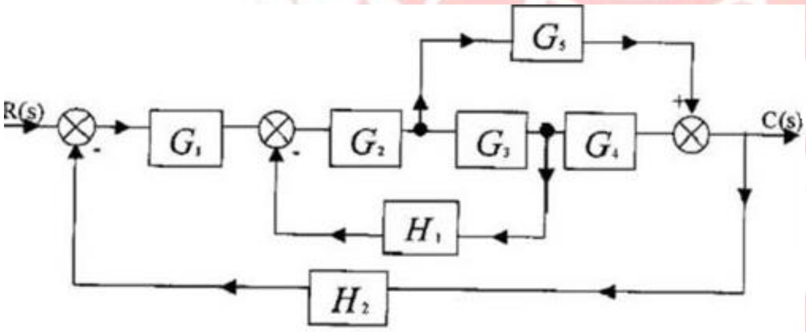


Fig(11)



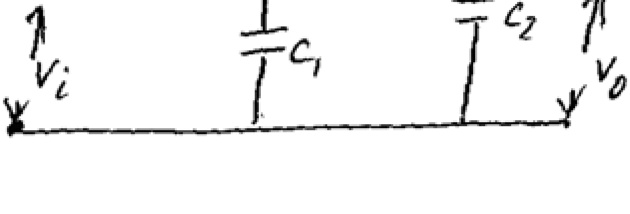
Fig(12)

10. Determine the Transfer function using block reduction and SFG method



Fig(13)

11. Determine the Transfer function of the electrical network shown in the fig.



12.(i) Give the Comparison between block diagram and Signal flow graph methods.
(ii) State any four block diagram reduction rules.
(iii) Give the step by step procedure for determining transfer function using signal flow graph.

Unit – II Time Response Analysis

Part A

1. How a control system is classified depending on the value of damping?
2. Define type number and order of system:
3. What is the effect of PI controller on the system performance?
4. Define Kp, Kv, Ka .
5. Give the steady state errors to various standard inputs for type-2 system:
6. Define resonant peak and resonant frequency.
7. Why derivative controller is not used in Control systems?
8. The closed loop transfer function of a second order system is given by
$$\frac{400}{s^2 + 2s + 400}$$
9. Determine the Damping ratio and natural frequency of oscillation.
10. What is meant by peak overshoot?
11. What is meant by steady state error?
12. Define rise time.
13. The damping ratio and natural frequency of a second order system are o.5 and 8 rad/sec respectively. Calculate resonant peak and resonant frequency.
14. With reference to time response, define peak time.
15. What are transient and steady state response of control system?
16. What are the units of kp, kv, ka?
17. Sketch the response of the second order under damped system.
18. List the time domain specifications.
19. What are static error constants?
20. Define position, velocity error constants.
21. Define damping ratio.
22. Name the test signals used in time response analysis.
23. Define step signal.
24. Define ramp, parabolic and impulse signal.
25. Define peak time.

Part B

1.With the Suitable block diagrams and Equations, Explain the following type of controllers employed in Control Systems.

i. Proportional controller

ii. Proportional – plus – integral controller

iii. PID controller

iv. Integral controller

2.The Unity feedback system is characterized by the open loop transfer function $G(S) = k\ s(s+10)$. Determine the gain K, so that the system will have the damping ratio of 0.5. For this value of K, Determine the settling times, peak overshoot, and time to peak overshoot for a unit step input.

4. The open loop transfer function of a unity feedback control system is given by $(S) = k\ (sT+1)$ where K and T are positive constants. By what factor should the amplifier gain be reduced so that the peak overshoot of unit step response of the system is reduced from 75% to 25%.

5. Consider a Second order model $\frac{Y(s)}{R(s)} = \frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$; $0 < \varepsilon < 1$. Find the response y (t) to a unit step input. (or) Derive the response of underdamped second order system for unit step input.

6.Derive the Expression and Sketch the response of first order system for unit step input.

7.The closed loop transfer function of a second order system is given by $T(s) = \frac{100}{s^2+10s+100}$. Determine the damping ratio, natural frequency of oscillations, rise time, settling time and peak overshoot.

8.A unity feedback system is characterised by the open loop transfer function

$G(s) = \frac{1}{s(0.5s+1)(0.2s+1)}$. Determine the steady state errors for Unit-step, Unit- ramp and Unit- acceleration unit. Also determine the damping ratio and natural frequency of the dominant roots.

9. Derive an Expression to find steady state error of closed loop system.

10. A unit ramp input is applied to a unity feedback system whose transfer function is **$C(s)= 100/(s^2+5s+100)$**.Find the time response and steady state error.

11. i. A unity feedback system with unit step input for which open loop transfer function G(s) =16/s(s+8).Find the transfer function, the natural Frequency, the damping ratio and the damped frequency of oscillation.

12. The unity feedback system is characterized by an open loop transfer function $G(s) = K(2s+1)/ s(5s+1)(1+s)^2$ with r(t) = (1+6t). Find the minimum value of K if the steady error is to be less than 0.1.

13. Derive the Expression and Sketch the response of Second order system for unit step input.

14. Derive Expression for Rise time, fall time, settling time, peak overshoot. (or) Explain time domain specifications.

UNIT III - FREQUENCY RESPONSE

PART- A

1. Define resonant peak and resonant frequency:
2. Draw the Bode plot of an integral term transfer function.
3. Give the specifications used in frequency domain analysis:
4. Define phase margin and gain margin:
5. What are the advantages of Frequency Response Analysis?
6. What is the need for compensation?
7. What is Nyquist plot?
8. What is Lag-Lead compensation?
9. Sketch shape of polar plot for the open loop transfer function
   G(s)H(s) = $1/s(1+Ts)$
10. What are the effects of addition of open loop poles?
11. What are the advantages of Frequency Response Analysis?
12. Define gain crossover Frequency.
13. Name the Parameters which constitute frequency domain Specifications.
14. Derive the transfer function of a lead compensator network.
15. Define compensators and list types of compensators.
16. Derive the transfer function of a lead compensator network.
17. List the advantages of Nichol's chart
18. What is meant by corner frequency in frequency response analysis?
19. Draw the circuit of lead compensator and draw its pole zero diagram.
20. What are the specifications used in frequency domain analysis?
21. Compare series compensator and feedback compensator

22. Determine the Phase angle of the given transfer function

G(S) = 10 / S (1+0.4S) (1+0.1S)

23. What is meant by corner frequency in frequency response analysis?
24. Define the gain cross over frequency.
25. Draw the Bode plot of derivative term transfer function.

PART- B

1. Sketch the Bode plot for the following transfer function and determine K for the gain cross over frequency to be 5 rad/sec. $G(s) = \frac{Ks^2}{(1+0.2s)(1+0.02s)}$.

2. Sketch the Bode plot for the following transfer function and determine gain margin and phase margin $G(s) = \frac{75(1+0.2s)}{s(s^2+16s+100)}$.

3. Given $G(s) = \frac{Ke^{-0.2s}}{s(s+2)(s+8)}$, find K for the following two cases using Bode Plot : i) for gain margin equal to 6 db, ii) for Phase margin equal to 45 degrees.

4. The open loop transfer function of a unity feedback system is given by

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

Sketch the polar plot and determine the gain margin and phase margin.

5. The open loop transfer function of a unity feedback system is given by

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

Sketch the polar plot and determine the gain margin and phase margin.

6. The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{(1+0.2s)(1+0.025s)}{s^3(1+0.005s)(1+0.001s)}$$

Sketch the polar plot and determine and phase margin.

7. Plot the Bode plot for $G(s) = \frac{10}{s(1+0.4s)(1+0.1s)}$ and obtain the gain and phase cross over frequencies.

8. Draw the polar plot for the following transfer function $G(s) = \frac{10(s+2)}{s(s+1)(s+3)}$. Find gain margin and phase margin.

9. The open loop transfer function of a unity feedback system is given by $G(s) = \frac{1}{s(1+s)^2}$. Sketch the polar plot and determine the gain margin and phase margin.

10.Consider a unity feedback system having an open loop transfer function $G(s) = \frac{K}{s(1+0.5s)(1+4s)}$ determine the value of K so that
(i) Gain margin is 20db, (ii) phase margin is 300.

11. A unity feedback control system has $G(s) = \frac{5(1+2s)}{(1+4s)(1+0.25s)}$

Draw the Bode plot.

12. Sketch the Bode plot for the following transfer function and determine gain cross over frequency $G(s) = \frac{20}{s(1+3s)(1+4s)}$.

13. Explain in detail the procedure for Nichol’s chart with M and N circles.

14.(i) Write short note on constant M and N circles **(8)**
(ii) Describe about Lead –lag compensators design procedure: **(8)**

UNIT IV - STABILITY ANALYSIS

Part A

1. State any two limitations of Routh-stability criterion.
2. Define stability of a system.
3. State Nyquist stability criterion.
4. Define Routh Hurwitz stability criterion.
5. What is the advantage of using root locus for design?
6. State the rules to obtain the breakaway point in root locus.
7. What is BIBO stability Criterion?
8. What is Centroid?

9. What is Root locus?
10. State the necessary and sufficient condition for stability.
11. What are the effects of addition of open loop poles?
12. Name the Parameters which constitute frequency domain Specifications.
13. What is characteristic equation?
14. How will you find the root locus on real axis?
15. How the roots of characteristic are related to stability?
16. What do you mean by dominant pole?
17. What are the regions of root locations for stable, unstable and limitedly stable systems?
18. . What are asymptotes? How will you find the angle of asymptotes?
19. Using Routh Criterion, determine the stability of the system represented by the characteristic equation
    $S^4+8S^3+18S^2+16S+5=0$.
20. State the rule for obtaining the breakaway point in root locus:
21. State any two limitations of Routh Stability Criterion:
22. Define stability of a system:
23. What is Nichol's chart?
24. Draw the polar plot of G(s)= 1/(1+ST)
25. State the advantages of Nyquist stability criterion over that of Routh's criterion.

Part B

1. Sketch the root locus of the system whose open loop transfer function is
   $G(s)=\frac{K}{s(s^2+4s+13)}$.
2. Sketch the root locus of the system whose open loop transfer function is
   $G(s)=\frac{K}{s(s+2)(s+4)}$. Find the value of K so that the damping ratio of the closed loop system is 0.5.
3. The open loop transfer function of a unity feedback system is given by
   $G(s)=\frac{K(s+9)}{s(s^2+4s+11)}$. Sketch the root locus of the system.

4. Using Routh criterion, determine the stability of the system represented by the characteristic equation i) $s^4+8s^3+18s^2+16s+5=0$.
   ii) $s^6+2s^5+8s^4+12s^3+20s^2+16s+16=0$

5. Using Routh criterion,

(i) Investigate the stability of a unity feedback control system whose open-loop transfer function is given by $G(s)=\frac{e^{-st}}{s(s+2)}$.

ii) Closed loop control system has the characteristics equation

$S^3+4.5S^2+3.5S+1.5 = 0$.

6. (i) Determine the range of K for stability of unity feedback system whose open loop transfer function is G(s) = K /[s(s+1) (s+2)] using routh stability criterion. **(6)**

ii) Determine the range of K for stability of unity feedback system whose open loop transfer function is $G(s) = \frac{K}{(s+2)(s+4)(s^2+6s+25)}$ using routh stability criterion. **(10)**

7. Sketch the root locus of the system whose open loop transfer function is $G(s) = \frac{K}{s(s^2+6s+10)}$.

8. Sketch the root locus of the system whose open loop transfer function is $G(s)H(s) = \frac{K}{s(s+4)(s^2+4s+20)}$.

9. Sketch the root locus of the system whose open loop transfer function is $G(s)H(s) = \frac{K(s+1.5)}{s(s+1)(s+5)}$.

10. Sketch the root locus of the system whose open loop transfer function is $G(s)H(s) = \frac{K(s^2+6s+25)}{s(s+1)(s+2)}$.

11 (i) A unity feedback system is characterized by the open loop transfer function $G(s) = K/[(s+2)(s^3+10s^2+49s+100)]$. Using Routh stability criterion calculate the range of K for system to be stable. Determine the value of K, which will cause sustained oscillations in the closed loop system. Also, determine the frequency of sustained oscillations. **(10)**

(ii) State the rules for construction of the root locus for a feedback system: **(6)**

12 (i) A certain unity negative feedback control system has the following open loop transfer function $G(s)H(s) = K/[s(s+2)(s^2+2s+5)]$. Find the breakaway points and draw root locus for $0 \le \omega \le \infty$ **(10)**

(ii) List the advantages of Routh's array method of examining stability of a control system: **(6)**

13. Draw the approximate root locus diagram for a closed loop system whose open loop transfer function is given by $G(s) = K /[s(s+5) (s+10)]$. Comment on the stability. **(16)**

UNIT V- STATE VARIABLE ANALYSIS

PART- A

1. Write the properties of State transition matrix?
2. Determine the controllability of the system described by the state equation.
3. What is meant by sampling theorem?
4. Mention the need for State variables.
5. What is meant by quantization?
6. Define State and State Variable.
7. Define State equation.
8. Give the concept of Controllability.
9. What is meant by Sampled –data Control System?
10. What are the advantages of State Space approach?
11. What is Alias in sampling process?
12. Name the methods of state space representation for phase variables.
13. What is meant by quantization?
14. Determine the controllability of the system described by the state equation.
15. How the modal matrix is determined?
16. What are the advantages of Sate Space representations?
17. What is Observability?
18. What are sampler and hold circuits.
19. Define Open loop sampled data systems.
20. Define closed loop sampled data systems.
21. Draw the block diagram of sampled data control system.
22. Derive the expression for the transfer function from the state model
    $\dot{x}$ = Ax + Bu ,y=Cx+Du
23. What is sampled data control system.
24. What are the advantages of sampled data control system.
25. What is the equivalent representation of pulse sampler with ZOH?

Part B

1. Test the controllability and observability of the system whose state space representation is given as: (16 marks)

$$\begin{bmatrix} \dot{x}1 \\ \dot{x}2 \\ \dot{x}3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 2 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix}$$

2. Determine the controllability and observability of the following system

$$\begin{bmatrix}\dot{x}1\\ \dot{x}2\\ \dot{x}3\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 0 & -2 & -3\end{bmatrix}\begin{bmatrix}x1\\ x2\\ x3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 10\end{bmatrix} u$$

$$y = \begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}x1\\ x2\\ x3\end{bmatrix}$$

1. Consider the system with the state equation.

   $$\begin{bmatrix}\dot{x}1\\ \dot{x}2\\ \dot{x}3\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -6 & -11 & -6\end{bmatrix}\begin{bmatrix}x1\\ x2\\ x3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix} u$$

   Check the controllability of the system.

2. Check the controllability and observability properties of the following system

   $$A = \begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 0 & -2 & -3\end{bmatrix}; B = \begin{bmatrix}0\\ 0\\ 1\end{bmatrix}; \quad C = \begin{bmatrix}10 & 0 & 0\end{bmatrix}$$

3. The state space representation of a system is given below:

   $$\begin{bmatrix}\dot{x}1\\ \dot{x}2\\ \dot{x}3\end{bmatrix} = \begin{bmatrix}-2 & 1 & 0\\ 0 & -3 & 1\\ -3 & -4 & -5\end{bmatrix}\begin{bmatrix}x1\\ x2\\ x3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix} u$$

   $$y = \begin{bmatrix}0 & 1 & 0\end{bmatrix}\begin{bmatrix}x1\\ x2\\ x3\end{bmatrix}$$. Obtain the transfer function.

4. Derive transfer function corresponding to the following state variable. (16)

$$\dot{x} = \begin{bmatrix} -6 & 1 & 0 \\ -11 & 0 & 1 \\ -6 & 0 & 0 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} + \begin{bmatrix} 2 \\ 6 \\ 2 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix}$$

5. Determine the transfer matrix from the data given below: **(8)**

$$A = \begin{bmatrix} -3 & 1 \\ 0 & -1 \end{bmatrix} \quad B = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & 1 \end{bmatrix} \quad D = 0.$$

(ii) The transfer function of a control system is given by

$$\frac{Y(s)}{U(s)} = \frac{s+2}{s^3 + 9s^2 + 26s + 24}.$$

Check for controllability. **(8)**

6. A system is represented by the characteristic equation X=AX+BU; Y = CX; where A, B and C are given below: determine the transfer function: (16)

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & -1 & -10 \end{bmatrix}, \ B = \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} \text{ and } C = [100]$$

7. (i) State and explain sampling theorem: **(4)**

(ii) A discrete system is described by the difference equation

y(k+2)+5 y(k+1)+6y(k) = u(k); y(0) = y(1) =0; T = 1 sec. Determine the state model in canonical form. Draw the block diagram. **(12)**

8. Determine the state controllability and observability of the system described by the following matrices: (16 marks)

$$\dot{\bar{x}} = \begin{bmatrix} -3 & 1 & 1 \\ -1 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} x + \begin{bmatrix} 0 & 1 \\ 0 & 0 \\ 2 & 1 \end{bmatrix} u \qquad y = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} x$$

11i).Check the controllability and observability of the system represented by the following state equation: (8 marks)

$$\begin{bmatrix}\dot{x}1\\ \dot{x}2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\begin{bmatrix}x1\\ x2\end{bmatrix} + \begin{bmatrix}1\\ -1\end{bmatrix} u \quad ; \quad y = [1 \quad 0] \begin{bmatrix}x1\\ x2\end{bmatrix}$$

11ii).The transfer function of a control system is given by (8 marks)

$\frac{Y(s)}{U(s)} = \frac{s+2}{s^3+9s^2+26s+24}$. Check for controllability.

12 i)Check the controllability of the following state space system.

$\dot{x}1 = x_2 + u_2$
$\dot{x}2 = x_3$
$\dot{x}3 = -2x_2 - 3x_3 + u_1 + u_2$

12 ii)Obtain the transfer function model for the following state space system.

A=$\begin{bmatrix}0 & 1\\ -6 & -5\end{bmatrix}$ B= $\begin{bmatrix}1\\ 0\end{bmatrix}$ C=[1 0] D=[0]

13 i)Obtain the state model of the system described by the following transfer function

$\frac{Y(s)}{U(s)} = \frac{5}{s^3+6s+7}$.

13 ii)Obtain the state transition matrix for the state model whose system matrix A is given by A=$\begin{bmatrix}1 & 1\\ 0 & 1\end{bmatrix}$

14. Find the canonical form of representation and state transition matrix. (16 marks)

$$\begin{bmatrix}\dot{x}1\\ \dot{x}2\\ \dot{x}3\end{bmatrix} = \begin{bmatrix}2 & -2 & 3\\ 1 & 1 & 1\\ 1 & 3 & -1\end{bmatrix}\begin{bmatrix}x1\\ x2\\ x3\end{bmatrix} + \begin{bmatrix}11\\ 1\\ -14\end{bmatrix} u$$

$$y = [-3 \quad 5 \quad -2] \begin{bmatrix}x1\\ x2\\ x3\end{bmatrix}$$

15i).A System is characterized by the Transfer function $\frac{Y(s)}{U(s)} = \frac{3}{s^3+5s^2+11s+6}$.

Determine whether or not the system is completely controllable and observable

15ii)State and explain sampling theorem. (4 marks)

16i) A feedback system has the following transfer function $\frac{C(s)}{R(s)} = \frac{10S}{(S+1)(S+2)(S+3)}$. Construct the state model for this system. (8 marks)

16ii) Explain the analysis of sample and Hold operation and draw the practical Sample and Hold circuit. (8 marks)