IC6501 CONTROL SYSTEMS

UNIT I

SYSTEMS AND THEIR REPRESENTATION

Part-A

1. What is control system?

A system consists of a number of components connected together to perform a specific function. In a system when the output quantity is controlled by varying the input quantity then the system is called control system.

2. Distinguish between open loop and closed loop system

S.No	Open Loop	Closed Loop
1	Inaccurate	Accurate
2	Simple and Economical	Complex and Costlier
3	The change in output due to external disturbance are not corrected	The change in output due to external disturbance are corrected automatically
4	May oscillate and become un stable	They are generally stable

3. Define transfer function.

The Transfer function of a system is defined as the ratio of the laplace transform of output to Laplace transform of input with zero initial conditions.

4. Write Masons Gain formula.

Mason‘s gain formula states that the overall gain of the system as follows Overall gain,

T = T(S) = transfer function of the system

K= Number of forward path in the signal flow.

P_K = forward path gain of the Kth forward path

Δ = 1 –(Sum of individual loop gains) + (Sum of gain products of all possible combinations of two non-touching loops) -(Sum of gain products of all possible combinations of three non-touching loops) + ……. Δk = (Δ for that part of the graph which is not touching Kth forward path)

5. Mention the advantage and disadvantage of block diagram reduction technique.

Advantages:

System can be easily analyzed.

It gives the information above performance of the system

Disadvantages:

It is not unique

It is time consuming procedure

6. What are the basic elements in the control system?

The basic elements are

Controlled variable

Plant

Feedback

Distrubances

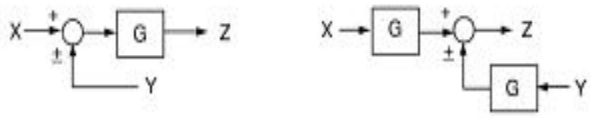
7. Write down the application of Synchros.

Stepper motor, Robot actuators,Posistioning of machines,tape recorder tunables**.**

8. Why is negative feedback invariably preferred in closed loop system?

The negative feedback is preferred in closed loop control systems because it has better stability and rejects disturbance signals.

9. List any two rules on Block diagram reduction techniques.



Moving a summer beyond the block

Cascaded blocks

10. Write the differential equation of Dashpot.

$f = f_b = B\ dX/dt$

11.Define Linear and Nonlinear System.

A system is said to be **linear**,if it **obeys** the superposistion &homogeneity principle.(weighted sum of the signal is equals to the weighted sum of individual input signals). A system is said to be **non linear**,if **it doesnt** obeys the superposistion &homogeneity principle.

12.Define Time variant and time invariant system

When there is no nonlinearities in times varing system then that the system is called as linear time variant .While operating the control system if the parameters are unaffected by time then the system is called as Time Invariant Control system

13.What is a signal flow graph?

A signal flow graph is a diagram that represents a set of simultaneous algebraic equations.

It is used to represent the control system graphically. It represents the flow of signals from one point of a system to another.

14.What is analogous System?

When a system remains analogous as long as the differential equation governing the system or transfer function or in identical form. Ex. Electrical analogous system.

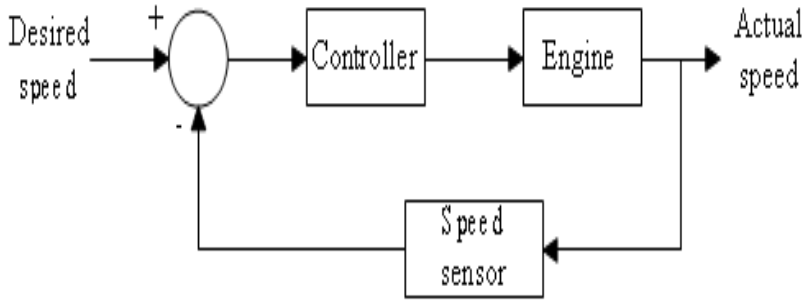
15.Define Non touching loop

The loops are non touching if they dont posesses any common node.

16.What is synchro?

A commonly used error detector of mechanical posistion of rotating shaft in ac control system is the Synchro

17.Draw the general block diagram of closed loop system?



18.What is the need for block diagram reduction?

The block diagram can be used to reduce over all transfer function of the system.

19.What is the application of AC Servo system?

Robotics, Conveyor belt, solar tracking system, Automatic door opening

20.What are the advantage of closed loop system?

Accurate , they are generally stable, the change in output due to external disturbance are corrected automatically.

Part-B

1. Compare the open and closed loop control system is distinguished with closed loop system.

2.Write the differential equations governing the mechanical rotational system as shown in figure.

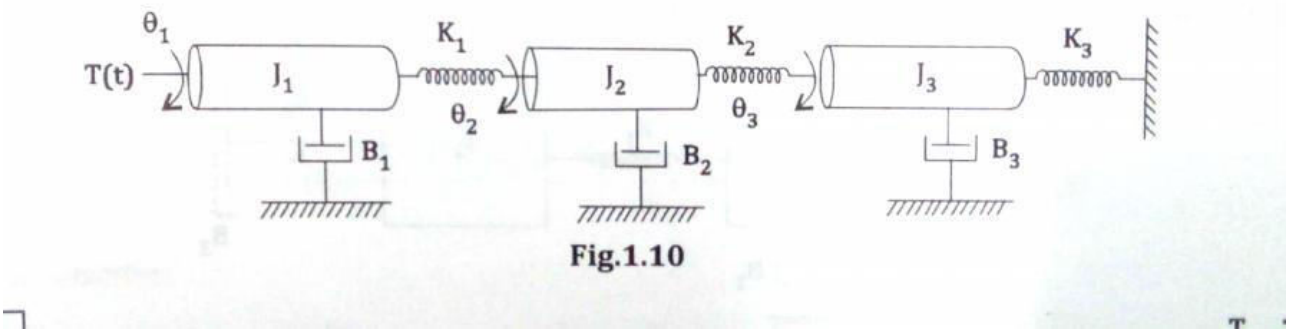
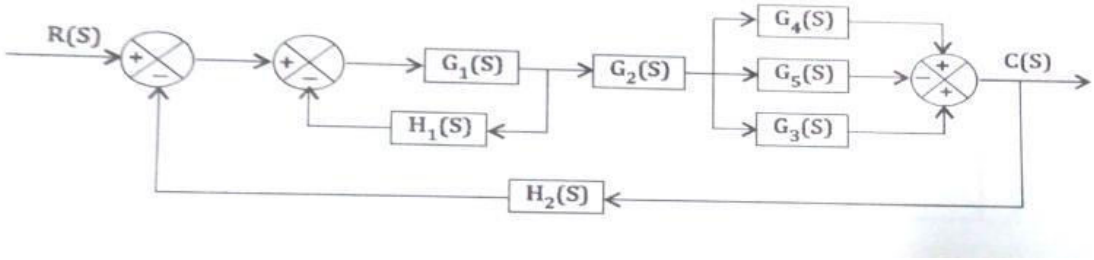


Fig.1.10

3.Compose the given block diagram shown in fig to signal flow graph and determine the closed loop transfer function C(s)/R(s).

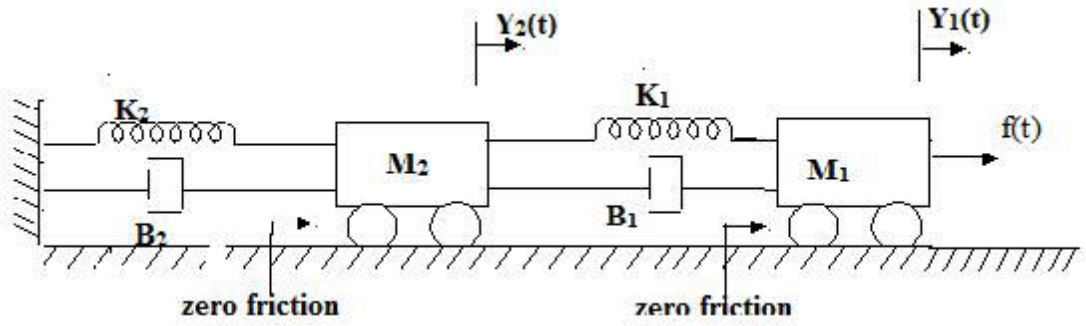


4.Differentiate DC and AC servomotor.

5.Explain open loop and closed loop control systems with examples

6.Derive the transfer function of an armature controlled DC servomotor

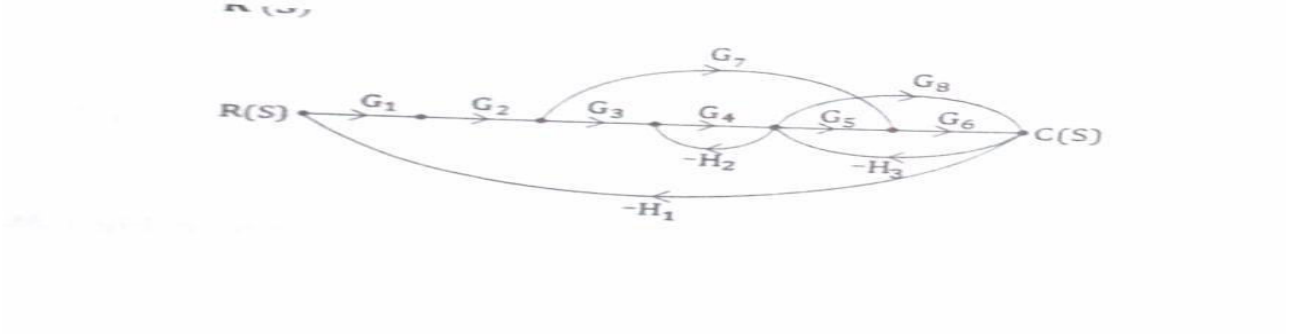
For the mechanical system given in Fig . 1. Show the mechanical network diagram andhence write the differential equations describing the behaviour of the system. Show the force voltage and force current analogous electricalcircuits



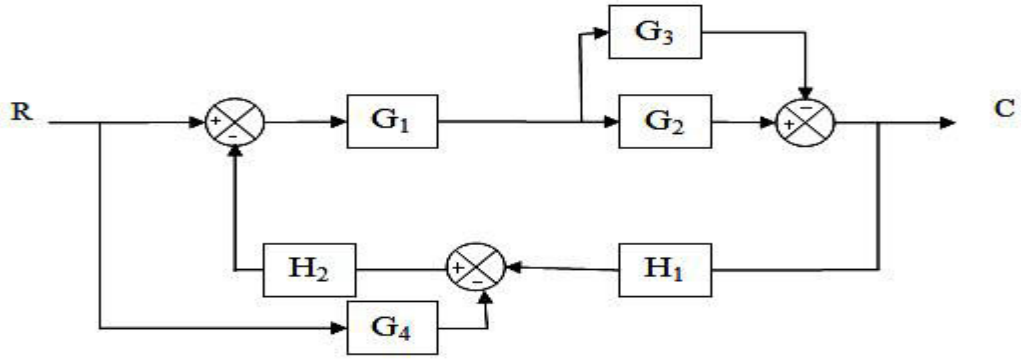
7.With neat diagrams, Discuss the working of AC servo motor

8.Estimate the Transfer function of field Controlled DC servo motor

9.Describe the Mathematical Modelling of fundamental component of mechanical rotational system.Identify the overall gain C(s) / R(s) for the signal flow graph shown below



10.Formulate the transfer function for the block diagram shown in Figure. using the block diagram reduction technique. (ii) using Mason's Gain Formula.



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UNIT II
TIME RESPONSE
PART-A

1. **What is the type &order of a system? What is its significance?**
   The order of the system is given by the order of the differential equation governing the system. It is also given by the maximum power of s in the denominator polynomial of transfer function. The type number is given by number of poles of loop transfer function at the origin. The type number of the system decides the steady state error.

2. **Define Peak time**
   It is the time taken for the response to reach the peak value for the very first time (or) It is the time taken for the response to reach peak overshoot, Mp .

3. **What is a dominant pole?**
   The dominant pole is a air of complex conjugate pair which decides the transient response of the system.

4. **Define Peak overshoot**.
   Peak overshoot is defined as the ratio of the maximum peak value measured from final value to final value.

5. **What is breakaway point?**
   The point at which the root locus breaks from real axis to imaginary axis is called breakaway point.

6. **What is centroid, how it is calculated?**

   The meeting point of the asymptotes with real axis is called centroid.

   $$\text{Centroid} = \frac{sum\ of\ poles - sum\ of\ zeros}{no.of\ poles - no.of\ zeros}$$

7. **What are type 0 and type 1 system?**
   The no of poles at origin decides the type no of the system, if N=0 for type 0 system & if N= 1 for type 1 system

8. Define damping ratio.

The damping ratio is defined as the ratio of actual damping to critical damping.

9. Name the test signals used in control system

The commonly used test input signals in control system are impulse, step, ramp, parabolic and sinusoidal signals.

10. What is break in point?

The point at which the root locus enters from imaginary axis to real axis is called break in point.

11. What is the effect of PD controller on the system performance?

The effect of PD controller is to increase the damping ratio of the system and so the peak overshoot is reduced

12. List the time domain specifications.

The time domain specifications are i. Delay time ii. Rise time iii. Peak time iv. Peak overshoot

13. What are the three constants associated with a steady state error?

The three steady state errors constant are

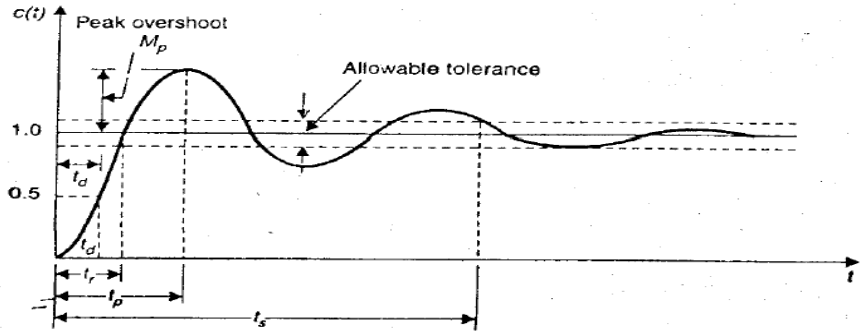
Positional error constant Kp
Velocity error constant Kv
Acceleration error constant Ka

14. How the system is classified depending on the value of damping.

Depending on the value of damping, the system cen be classified into the following four cases

Case 1: Undamped system
Case 2: Under damped system
Case 3: critically damped system
Case 4: over damped system

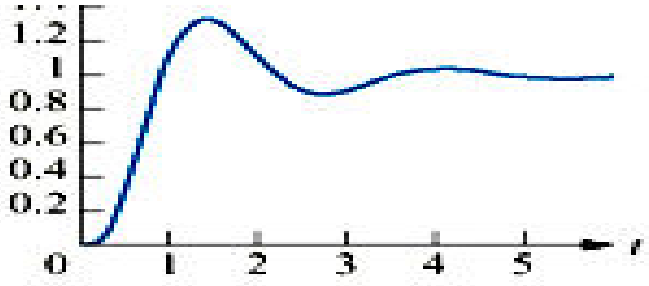
15.Sketch the time domain response of Second order system



16.Co relate the static and dynamic error coefficients

$C_0=1/(1+k_p)$; $C_1=1/k_v$; $C_2=1/k_a$

17.Sketch the response of II order under damped system



Part-B

1.Describe the time domain specifications of a second order system.

2.Identify the expression for the unit step response of a second order
(1)underdamped
(2)undamped system

3.Explain briefly the PID controller action with block diagram and obtain the transfer function model.

4.Evaluate the expression for dynamic error coefficients of the following system

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

5.Develop the time response of a typical under damped second order system for a unit step input.

6.Explain the rules to construct root locus of a system

7.With a neat diagram explain the effect of PD controller in detail.

8.Compute the static error coefficients for a system whose G(s) H(s) =10/ s (1+s) (1+2s) and also find the steady state error for r(t)=1+ t + t2/2.

9.Draw the root locus for a system is given by

$$G(s) = \frac{K(s+1)}{s(s^2+5s+20)}$$

UNIT III

FREQUENCY RESPONSE

1. **Define Gain margin and phase margin**.
   It is defined as the amount of gain(in dB) added to the system to make the system unstable.
   It is defined as the amount of phase lag(in degrees) added to the system to make the system unstable

2. **Define phase margin**.
   It is defined as the amount of phase lag(in degrees) added to the system to make the system unstable

3. **What is meant by corner frequency in frequency response analysis?**
   The frequencies corresponding to the meeting point of the asymptotes are called corner frequency. The slope of the magnitude changes at every corner frequency.

4. **What is M and N circles?**
   The magnitude of closed loop transfer function with unity feedback can be shown in the form of circles for every value of M is called M circles.

5. **What is N circles?**
   The phase of closed loop transfer function with unity feedback can be shown in the form of circles for every value of N is called N circles.

6. **Define resonant peak and resonant frequency.**
   The maximum value of amplitude of the closed loop transfer function is called resonant peak. The frequency at which resonant peak occurs is called resonant frequency

7. **Define band width**.
   The range of frequencies for which the system normalized gain is more than -3 Db

8. **Define Phase cross over frequency?**
   The frequency at which, the phase of open loop transfer functions is 180° is called phase cross over frequency ωpc.

9. **Define Gain cross over frequency ?**
   The gain cross over frequency ωgc is the frequency at which the magnitude of the open loop transfer function is unity.

10. **What is Bode plot?**
    The Bode plot is the frequency response plot of the transfer function of a system. A Bode plot consists of two graphs. One is the plot of magnitude of sinusoidal transfer function versus log ω.The other is a plot of the phase angle of a sinusoidal function versus log ω.

11. **What is polar plot?**
    The polar plot of a sinusoidal transfer function G(jω) is a plot of the magnitude of G(jω) Vs the phase of G(jω) on polar co-ordinates as ω is varied from 0 to ∞. (ie) |G(jω)| Vs angle G(jω) as ω → 0 to ∞.

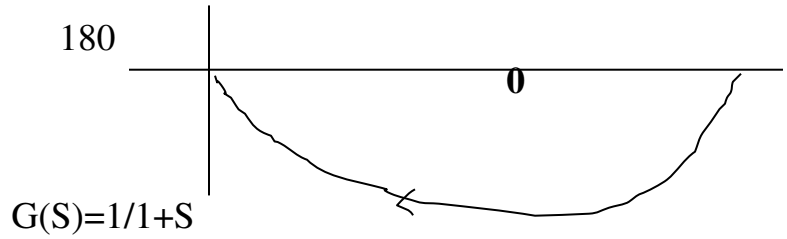
12. **List out the different frequency domain specifications?**
    The frequency domain specifications are Resonant peak, Resonant frequency. Bandwidth, Cut-off rate, Gain margin, Phase margin

13. **List out the different frequency domain plots?**
    Polar plot, Bode plot, Nichols plot, M & N circles

14. Define Cut-off rate?

The slope of the log-magnitude curve near the cut-off is called cut-off rate. The cut-off rate indicates the ability to distinguish the signal from noise.

15. Draw the polar plot of type 0 system?



16. What are the three types of compensators?

The three types of compensators are

i. Lag compensator. ii. Lead compensator. iii. Lag-Lead compensator.

17. What is the necessity of compensastion ?

Compensastion is the technique used to make the unstable system into a stable system by introducing the poles and zeros at suitable place.

18. What are the advantages of Niochol's chart?

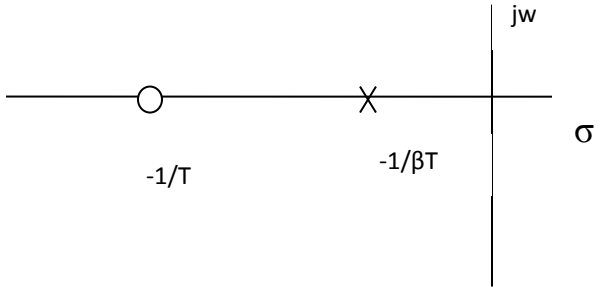
It is used to find the closed loop frequency response from open loop frequency response.Frequency domain specifications can be determined from Nichol's Chart.

Gain of the system can be adjusted to satisfy the given specifications.

19. When lag/lead/lag-lead compensation is employed?

Lag compensation is employed for a stable system for improvement in steady state performance. Lead compensation is employed for stable/unstable system for improvement in transient state performance. Lag-Lead compensation is employed for stable/unstable system for improvement in both steady state and transient state performance

20.Plot the pole zero plot of lag compensator



PART-B

1.Describe the use of Nichol's chart to obtain closed loop frequency response from open loop frequency response of a unity feed back system.

2.Describe the correlations between time and frequency domain specifications

3.With Mathematical expression define the following Frequency Domain specifications (i) Gain Margin (ii) Phase Margin (iii) Gain Cross over Frequency (iv) Phase Cross over Frequency (v) Resonant Peak (vi) Resonant Frequency (vii) Bandwidth

4.Draw and show the Bode plot for the open loop transfer function of a unity feedback system G(s)=10(S+3)/S(S+2)(S2+3S+25) and Determine : (i) Gain Margin (ii) Phase Margin (iii) Gain Cross Over Frequency (iv) Phase Cross Over Frequency

5.The Open Loop Transfer Function G(S)=K/S(1+0.5S)(1+4S). Determine the values manually calculate (i) Gain Margin (ii) Phase Margin (iii) Gain Cross Over Frequency (iv) Phase Cross Over Frequency(v) Stability range K.

6.What is meant by Compensator? Summarize the following effects of compensator (i) Lead Compensator (ii) Lag Compensator (iii) lead Lag compensator withy suitable transfer function.

7.Develop the Bode plot for the open loop transfer function of a unity feedback system G(S)=10/S(S+2)(S+6) and Determine : (i) Gain Margin (ii) Phase Margin (iii) Gain Cross Over Frequency (iv) Phase Cross Over Frequency

8.Draw and show the polar plot of the system open loop transfer function with unity feedback system given by G(S)=10/S(S+1)(S+4) Determine the phase and gain margin

9.The Second Order System has the closed loop transfer function C(S)/R(S)=8/(S2+4S+8). Calculate the following Frequency Domain specifications (i) Resonant Peak (ii) Resonant Frequency (iii) Bandwidth.

10.Construct Polar plot for the system G(S)=5(S+10)/S(S+2)(S+6) whose open loop transfer function is given below and Calculate (i)Gain margin (ii) Phase Margin (iii) Gain Cross-over Frequency (iv) Phase Cross over Frequency (v) Stability

UNIT IV
STABILITY AND COMPENSATOR DESIGN

1. **State Nyquist stability criterion**.
   If the Nyquist plot of the open loop transfer function G(s)H(s) corresponding to the Nyquist contour in the s-pla
   ne encircles the critical point -1+j0 in the counter clockwise direction as many times as the number of right half of s plane pole of G(s)H(s) the closed loop system is stable.

2. **What is a compensator?**
   A device inserted into the system for the purpose of satisfying the specifications is called as a compensator

3. **What is limitedly stable system?**
   For bounded input signal, if the output has constant oscillation then the system may be stable or unstable under some conditions. Such a system is called limitedly stable.

4. **What is BIBO stability?**
   A linear relaxed system is said to be BIBO stable, if every bounded input produces a bounded output.

5. **What is Routh Stability criterion?**
   All the elements of first column of the Routh array be positive
   If this condition is not met, then the system is unstable and the number sign changes in the first column is equal to number of poles located in right half of the s-plane

6. Define relative stability.

Relative stability is the degree of closeness of the system, it is an indication of degree of stability.

7. What are the deficiencies (or) limitations of Routh's criterion?

It assumes that the characteristic equation available in polynomial form Routh array may show no sign change in the first column but due to the dynamic characteristics the system may be relatively unstable. It gives only about relative stability

8. What is the necessary condition for stability?

Necessary condition for stability is that all the coefficients of characteristic polynomial be positive

9. What are the advantages of Nyquist stability criterion?

We can predict the closed loop stability from open loop data.
It can be modified for non-linear systems.
It gives relative stability of the system.

10. What are the effects of addition of open loop poles?

Relative stability of the closed loop system is reduced due to the addition of open loop poles.

11. What are the effects of adding a zero to a system?

Relative stability of the closed loop system is increased due to the addition of open loop poles. Adding complex zero makes the system more stable.

12. When is lag-lead compensator is required?

The lag lead compensator is required when both the transient and steady state response of a system has to be improved.

13. When is lead compensator is required?

The lead compensator is required when the system is stable/unstable and requires improvement in transient state response

14. When is lag compensator is required?

The lag compensator is required when the system is stable and does not satisfy the steady state performance specifications.

15. When is lag compensator is required?

The lag compensator is required when the system is stable and does not satisfy the steady state performance specifications.

16. What is auxiliary polynomial?

In the construction of routh array a row of all zero indicates the existence of an even polynomial as a factor of given characteristic equation. In an even polynomial the exponents of S are even integers or zero only. This even polynomial factor is called auxiliary polynomial. The coefficients of auxiliary polynomial are given by the elements of the row just above the row of all zeros

17. What is angle criterion?

The angle criterion states that s=sa will be the point on the root locus if for that value of S the argument or phase of G(S)H(S) is equal to an odd multiple of 180°. (Sum of the angles of vectors from zeros to the point $s=s_a$)- (Sum of the angles of vectors from poles to the point s=sa) = $\pm 180°(2q + 1)$

18. What are dominant zeros?

The zeros which are located near the imaginary axis are called dominant zeros.

19. For a system having non-repeated roots on the imaginary axis, comment about the stability of the system.

The system will be under sustained oscillations as it has roots on the imaginary axis

20. In Routh array what conclusion you can make when there is a row of all zeros?

It indicates that there is a possibility poles in the imaginary axis. It also indicates the existence of even polynomial as a factor of given characteristic equation

PART-B

1. Construct Routh's array and estimate the stability analysis of the system represented by the characteristic equation and comment on the location of roots.

$$s^5 + s^4 + 2s^3 + 2s^2 + 3s + 5 = 0$$

$$s^7 + 5s^6 + 9s^5 + 9s^4 + 4s^3 + 20s^2 + 36s + 36 = 0$$

2.Use R-H criterion to determine the location of the roots and stability for the system represented by characteristic equation

$$s^5 + 4s^4 + 8s^3 + 8s^2 + 7s + 4 = 0$$

3.Write the procedure for the design of Lag compensator using Bode plot. Obtain Routh's array for the system whose characteristic polynomial equation is

$$s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0$$

4.Define Nyquist stability criterion and explain the different situations of it.

5.Draw the Nyquist plot for the system whose open loop transfer function

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

6.Determine the range of K for which closed loop system is stable

UNIT-5

STATE VARIABLE ANALYSIS

1. **Define controllability.**

   A system is said to be completely state controllable if it is possible to transfer the system state from any initial state $X(t_0)$ to any desired state X(t) in a specified finite time by a control vector u(t).

2. **Define observability**.

   A system is said to be completely observable if every state X(t) completely identified by the measurements of the output Y(t) in a finite time interval.

3. **What are the test to be carried out to find the controllability and observability?**

   Gilbert's test
   Kalman's test

4. **What is state?**

   The state of a dynamic system is defined as a minimal set of variables.

5. How controllability of the system is determined?

A general n^{th} order multi input LTI system X'=AX+BU is completely controllable if and only if the rank of the composite matrix,

$Q_c=[B: AB: A^2B:\ldots\ldots:A^{n-1}]$ is n.

6. How observability of the system is determined?

A general n^{th} order multi input LTI system X'=AX+BU and Y=CX is completely observable if and only if the rank of the composite matrix,

$Q_o=[C^T: A^TC^T: \ldots\ldots:(AT)^{n-1}C^T]^T$ is n.

7. What are the necessities of state space analysis?

Applicable to MIMO systems.
Initial conditions can be included.
It gives information regarding the internal state of the system.

8. What is state space representation?

It consist of two equations one is state equation and another one is output equation.

9. State the advantages of using canonical variables.

1. The matrix A is diagonal
2. The diagonal element is very important in the mathematical analysis
3. Due to diagonal feature the decoupling between the state variable is possible.

10. Define state variable.

The state of a dynamical system is a minimal set of variables(known as state variables) such that the knowledge of these variables at t-t0 together with the knowledge of the inputs for t > t0 , completely determines the behavior of the system for t > t0

11. Write the general form of state variable matrix.

The most general state-space representation of a linear system with m inputs, p outputs and n state variables is written in the following form: = AX + BU Y = CX + DU Where = state vector of order n X 1.

U = input vector of order n X1. A=System matrix of order n X n. B=Input matrix of order n X m C =output matrix of order p X n D = transmission matrix of order p X m

12. Write the relationship between z-domain and s-domain. All the poles lying in the left half of the S-plane, the system is stable in S-domain. Corresponding in Z-domain all poles lie within the unit circle.

13. What is the necessary condition to be satisfied for design using state feedback?

The state feedback design requires arbitrary pole placements to achieve the desire performance. The necessary and sufficient condition to be satisfied for arbitrary pole placement is that the system is completely state controllable.

14. Write the properties of state transition matrix.

The following are the properties of state transition matrix

1. Φ (0) = eAx0 = I (unit matrix).
2. Φ (t) = eAt = (e-At)-1 = [Φ(-t)]-1.
3. Φ (t1+t2) = eA(t1+t2) = Φ(t1) Φ(t2) = Φ(t2) Φ(t1).

15. What is modal matrix?

The modal matrix is a matrix used to diagonalize the system matrix. It is also called diagonalization matrix. If A = system matrix. M = Modal matrix And M-1=inverse of modal matrix. Then M-1AM will be a diagonalized system matrix.

16. How the modal matrix is determined?

The modal matrix M can be formed from eigenvectors. Let m1, m2, m3 …. mn be the eigenvectors of the nth order system. Now the modal matrix M is obtained by arranging all the eigenvectors column wise as shown below.

Modal matrix , M = [m1, m2, m3 …. mn].

17. What is the need for controllability test?

The controllability test is necessary to find the usefulness of a state variable. If the state variables are controllable then by controlling (i.e. varying) the state variables the desired outputs of the system are achieved.

18. What is the need for observability test?

The observability test is necessary to find whether the state variables are measurable or not. If the state variables are measurable then the state of the system can be determined by practical measurements of the state variables.

19. State the condition for controllability by Gilbert's method.

Case (i) when the eigen values are distinct

Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ. = ΛZ + U Y=Z + DU Where, Λ = M-1AM; = CM , = M-1B and M = Modal matrix. In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable.

Case(ii) when eigen values have multiplicity In this case the state modal can be converted to Jordan canonical form shown below = JZ + U Y=Z + DU Where, J = M-

1AM In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero.

20. State the condition for observability by Gilbert's method.

Consider the transformed canonical or Jordan canonical form of the state model shown below which is obtained by using the transformation, $X = MZ = \Lambda Z + U$
$Y = Z + DU$ (Or) $= JZ + U$ $Y = Z + DU$ where $= CM$ and M=modal matrix.
The necessary and sufficient condition for complete observability is that none of the columns of the matrix be zero. If any of the column is of has all zeros then the corresponding state variable is not observable.

21.State the duality between controllability and observability.

The concept of controllability and observability are dual concepts and it is proposed by kalman as principle of duality.The principle of duality states that a system is completely state controllable if and only if its dual system is completely state controllable if and only if its dual system is completely observable or viceversa.

22.What is the need for state observer?

In certain systems the state variables may not be available for measurement and feedback. In such situations we need to estimate the unmeasurable state variables from the knowledge of input and output. Hence a state observer is employed which estimates the state variables from the input and output of the system. The estimated state variable can be used for feedback to design the system by pole placement.
What is meant by state space model ?. Evaluate the mathematical expression for the state space representation for the continuous system.

PART-B

1.Develop the expression of (i) Controllability (ii) Observability concept by the following methods (i) Gilbert's Method (ii) Kalman's Method.

2.With the case study Summarize (i) Armature control of DC Motor (ii) Field Control of DC Motor. And also draw the (i) Block diagram(ii) State diagram and state space model for the system

3.Formulate the controllable canonical realization of the following systems. Hence, obtain the state space model in controllable canonical form (i) H(S)=(S+2)/(S+5) (ii) H(S)=(S+2)/(S2+2S+5) (iii)H(S)=(2S+9)/(S3+8S2+12S+1) (iv)H(S)=(S2+2S+3)/(S4+3S3+12S2+9S+10)

4.Formulate the expression for the state space model for the continuous system and also draw the state diagram for it

5.Consider a system whose transfer function is given by Y(S)/U(S) = 10(S+1)/S3+6S2+5S+10 Evaluate the state model for the system (i) by Block diagram reduction (ii) Signal flow graph Method

6.Obtain and express the expression for the controllability and observability in (i) Kalman's Method

7.Consider a system with state space model is given below Point out that the system is observable and controllable.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 2 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 4 \end{bmatrix} U \quad ; y=[2\ -4\ \ 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$